1999 AMENDMENTS to the Program of Studies: Senior High Schools

1. **Replace** front-end pages i to v and Preamble pages 1 to 6 with **revised** front-end pages i to v and Preamble pages 1 to 6.

2. MATHEMATICS:

   - **Replace** Mathematics title page, following Mathematics divider.
   - **Replace** Mathematics Applied and Pure Programs, page 1 (following Mathematics title page) with **revised** Mathematics Applied and Pure Programs, page 1.
   - **Replace** Mathematics 20–30, pages 1 to 28 with Mathematics 30, pages 1 to 20.

3. SCIENCE:

   - **Replace** Science title page, following Science divider.
   - **Replace** Biology 20–30 page 1 with Biology 20–30 pages 1 to 69.
   - **Replace** Chemistry 20–30 page 1 with Chemistry 20–30 pages 1 to 51.
   - **Replace** Physics 20–30 page 1 with Physics 20–30 pages 1 to 69.

PROGRAM *of* STUDIES

Senior High Schools

This Program of Studies is issued under the authority of the Minister of Learning pursuant to section 25(1) of the *School Act*, Statutes of Alberta, 1988, Chapter S–3.1 with amendments in force as of March 26, 1998.

Alberta
LEARNING

This document reflects changes in the program of studies for senior high schools up to June 1999.

Outside Edmonton dial 310–0000 for toll-free connection. Inside Edmonton dial 422–4872.

PROGRAM OF STUDIES: SENIOR HIGH SCHOOLS

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The dates in the grid indicate the most current and up-to-date sections in each program of studies.

❶ Program information only.

Course **All programs of study are available for viewing and downloading at <http://ednet.edc.gov.ab.ca>.**	A. Program Rationale and Philosophy	B. General Learner Expectations	C. Curriculum Standards/ Specific Learner Expectations
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❶ Program information only.

Course All programs of study are available for viewing and downloading at <http://ednet.edc.gov.ab.ca>.	A. Program Rationale and Philosophy	B. General Learner Expectations	C. Curriculum Standards/ Specific Learner Expectations
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INTRODUCTION

Program of Studies

The *Program of Studies* identifies the expectations for the core and optional learning components for Kindergarten to Grade 12. Content is focused on what students are expected to know and be able to do.

Though organized into separate subject, course or program areas, there are many connections across the curriculum. Students see the world as a connected whole rather than as isolated segments. Integrating across content areas, and providing ways for students to make connections, enhances student learning. The reporting of student progress should, nevertheless, be in terms of the expectations outlined in courses of study for each subject area.

Within any group of students there is a range of individual differences. Flexibility in planning for individuals within a group is needed. Therefore, school organization and teacher methodology are not mandated at the provincial level and may vary from class to class and school to school in order to meet student needs.

For guidelines and regulations relating to school programs and organization for instruction, refer to the *Guide to Education: ECS to Grade 12*, available for viewing and downloading from the Internet. Print copies are available for purchase from the LRDC.

Basic Learning Resources

Alberta Learning authorizes a variety of resources to support the programs of study. Complete listings of all resources are to be found in the Learning Resources Distributing Centre (LRDC) *Buyers Guide*, or electronically through the:

- LRDC Internet web site at <http://www.lrdc.edc.gov.ab.ca>.

Resource listings can also be accessed through the:

- Authorized Resources Database at <http://ednet.edc.gov.ab.ca> under Students and Learning, Learning and Teaching Resources.

Internet Site

Information covering all areas of Kindergarten to Grade 12 education in Alberta, including curriculum and resources, can be found at <http://ednet.edc.gov.ab.ca>.

Information on-site is organized into sections focusing on Students and Learning; Parents; Teaching; Funding; Education System; and Technology.

PROGRAM FOUNDATIONS:
VISION, MISSION AND PRINCIPLES, AND BASIC EDUCATION★

Vision for Education

Alberta's young people are the best educated in the country, able to achieve their individual potential, create a positive future for themselves, their families and their communities, and contribute to Alberta's prosperity and superior quality of life.

Mission

To ensure that all Alberta students have the opportunity to acquire the knowledge, skills and attitudes needed to be self-reliant, responsible, caring and contributing members of society.

Principles

The *School Act* provides the legislative framework for sustaining and developing Alberta's education system. Students are the focus of the act, which is based on a set of five underlying principles.

- *Access to quality education*: Every student in Alberta has the right of access to a quality basic education which is consistent with the student's abilities and provides the necessary knowledge, skills and attitudes to fulfill personal goals and contribute to society as a whole.
- *Equity*: All students in Alberta must have access to a quality basic education regardless of where in the province they live.
- *Flexibility*: Within standards and policies set by the provincial government, there are opportunities for parent and student choice in the public education system. School boards, schools and individual teachers have flexibility to meet the educational needs of the students and communities they serve.
- *Responsiveness*: The student is the focus of all activities in the education system: legislation, policies and practices affecting all levels must support the efforts of communities to ensure school programs and services respond to the unique needs of each child.
- *Accountability*: All those involved in making decisions about educational matters, including the allocation of public funds for education, must be accountable for their decisions, choices and results. This includes the Minister of Learning, school boards and their staff, parents as well as students.

Guided by these principles, the three-year plan for education annually outlines improvements and directions for the education system consistent with the *School Act* (Statutes of Alberta, 1988, Chapter S–3.1 as amended, section 60.2, subsections 1 to 3).

Basic Education in Alberta—the Definition

A basic education must provide students with a solid core program, including language arts, mathematics, science and social studies. Students will be able to meet the provincial graduation requirements and be prepared for entry into the workplace or post-secondary studies. Students will understand personal and community values and the rights and responsibilities of citizenship. Students will develop the capacity to pursue learning throughout their lives. Students also should have opportunities to learn languages other than English and to attain levels of proficiency and cultural awareness which will help to prepare them for participation in the global economy.

★ Excerpted from *First Things First ... Our Children: The Government of Alberta's Three-year Plan for Education, 1999/2000 to 2001/2002.* The plan is available from the Communications Branch or can be found at <http://ednet.edc.gov.ab.ca>. Basic Education in Alberta—the Definition is contained in Ministerial Order Number 004/98 rather than in the three-year education plan.

Student Learning Outcomes

Students are expected to develop the knowledge, skills and attitudes that will prepare them for life after high school. A basic education will allow students to:

- read for information, understanding and enjoyment
- write and speak clearly, accurately and appropriately for the context
- use mathematics to solve problems in business, science and daily-life situations
- understand the physical world, ecology and the diversity of life
- understand the scientific method, the nature of science and technology, and their application to daily life
- know the history and geography of Canada and have a general understanding of world history and geography
- understand Canada's political, social and economic systems within a global context
- respect the cultural diversity and common values of Canada
- demonstrate desirable personal characteristics, such as respect, responsibility, fairness, honesty, caring, loyalty and commitment to democratic ideals
- recognize the importance of personal well-being, and appreciate how family and others contribute to that well-being
- know the basic requirements of an active, healthful lifestyle
- understand and appreciate literature, the arts and the creative process
- research an issue thoroughly, and evaluate the credibility and reliability of information sources
- demonstrate critical and creative thinking skills in problem solving and decision making
- demonstrate competence in using information technologies
- know how to learn and work independently and as part of a team
- manage time and other resources needed to complete a task
- demonstrate initiative, leadership, flexibility and persistence
- evaluate their own endeavours and continually strive to improve
- have the desire and realize the need for lifelong learning.

Standards for Student Learning

The Minister of Learning defines acceptable standards and standards of excellence for student achievement in consultation with Albertans. Employers are involved in specifying the knowledge, skills and attitudes needed in the workplace. Schools, school authorities and the Minister of Learning assess and report regularly to the public on a range of student learning.

The school's primary responsibility is to ensure that students meet or exceed the provincial standards, as reflected in the Student Learning Outcomes (outlined above), the Alberta Programs of Study, provincial achievement tests, diploma examinations and graduation requirements.

Education Delivery

Schools must engage students in a variety of activities that enable them to acquire the expected learnings. Schools have authority to deploy resources and may use any instructional technique acceptable to the community as long as the standards are achieved. Schools, teachers and students are encouraged to take advantage of various delivery options, including the use of technology, distance learning and the workplace.

Schools play a supportive role to families and the community in helping students develop desirable personal characteristics and the ability to make ethical decisions. Schools also help students take increasing responsibility for their learning and behaviour, develop a sense of community belonging and acquire a clearer understanding of community values and how these relate to personal values.

Students learn basic, transferable knowledge, skills and attitudes in school. Schools, in co-operation with employers, provide opportunities for students to develop and practise

employability skills. The Minister of Learning provides credit for off-campus learning that is approved and accepted by the school and the employer. Government works with schools, employers and post-secondary institutions to help young people make a smooth transition to work and further study.

RELIGIOUS AND PATRIOTIC INSTRUCTION

The following section of the *School Act* focuses on religious and patriotic instruction. It is cited here for the information of teachers and administrators.

SECTION 33(1) A board may

(a) prescribe religious instruction to be offered to its students;

(b) prescribe religious exercises for its students;

(c) prescribe patriotic instruction to be offered to its students;

(d) prescribe patriotic exercises for its students;

(e) permit persons other than teachers to provide religious instruction to its students.

(2) Where a teacher or other person providing religious or patriotic instruction receives a written request signed by a parent of a student that the student be excluded from religious or patriotic instruction or exercises, or both, the teacher or other person shall permit the student

(a) to leave the classroom or place where the instruction or exercises are taking place for the duration of the instruction or exercises, or

(b) to remain in the classroom or place without taking part in the instruction or exercises.

1988 cS–3.1 s33;1990 c36 s16

LEARNING RESOURCES

POLICY

Alberta Learning selects, acquires, develops, produces, translates and authorizes the best possible instructional materials for the implementation of approved programs of study.

LEARNING RESOURCE CATEGORIES

In terms of provincial policy, learning resources are those print, nonprint and electronic software materials used by teachers or students to facilitate teaching and learning. Many learning resources, both publisher-developed and teacher-made, are available for use in implementing elementary, junior high and senior high programs. Decisions about the selection and use of resources are a local matter and should take into account the student skill levels, interests, motivations and stages of development.

Alberta Learning authorizes learning resources in three categories:

- basic student learning resources
- support student learning resources
- authorized teaching resources.

Authorization indicates that the resources meet high standards and can contribute to the attainment of the goals of the program. However, the authorization of resources does not require their use in program delivery. Under section 44 (2) of the *School Act*, school boards may approve materials for their schools, including resources that are withdrawn from the provincial list. Many school boards have delegated this power to approve resources to school staff or other board employees under section 45 (1) of the *School Act*.

Basic Student Learning Resources

Basic learning resources are those student learning resources authorized by Alberta Learning as the most appropriate for addressing the majority of learner expectations of the course(s), substantial components of the course(s), or the most appropriate for meeting general learner expectations across two or more grade levels, subject areas or programs as outlined in provincial programs of study. These may include any resource format, such as print, nonprint, computer software, manipulatives or video.

In exceptional circumstances, a teacher resource may be given basic status.

Support Student Learning Resources

Support learning resources are those student learning resources authorized by Alberta Learning to assist in addressing some of the learner expectations of course(s) or components of course(s); or to assist in meeting the learner expectations across two or more grade levels, subject areas or programs as outlined in the provincial programs of study. These may include any resource format, such as print, nonprint, computer software, manipulatives or video.

Authorized Teaching Resources

Authorized teaching resources are those teaching resources produced externally to Alberta Learning (for example, by publishers) that have been reviewed by Alberta Learning, found to meet the criteria of review and to be the best available resources to support the implementation of programs of study and courses, and the attainment of the goals of education; they have been authorized by the Minister. Teaching resources produced as service documents by Alberta Learning are authorized by definition.

AVAILABILITY

Most authorized resources are available for purchase from the Learning Resources Distributing Centre (LRDC), 12360 – 142 Street, Edmonton, Alberta, Canada, T5L 4X9. Telephone 403–427–5775, Fax 403–422–9750, Internet <http://www.lrdc.edc.gov.ab.ca>.

Resources are listed in the Learning Resources Distributing Centre *Buyers Guide* and at the LRDC web site. Resources are also listed in the Authorized Resources Database at <http://ednet.edc.gov.ab.ca> under Students and Learning, Learning and Teaching Resources.

MATHEMATICS

CONTENTS

★The **revised** Mathematics 14–24 program of studies has interim approval effective September 1, 1999.

The **new** Mathematics Preparation 10 program of studies has interim approval effective July 1, 1999.

MATHEMATICS APPLIED AND PURE PROGRAMS

The new senior high school mathematics programs have been approved for use in Alberta schools on an interim basis and as outlined in the implementation schedule below.

Course Name	Credits	Course Code	Implementation Date	
			Optional	Provincial
Applied				
Mathematics 10	5	MAT1038	1998	2000
Mathematics 10b	3	MAT1040	1998	2000
Mathematics 20	5	MAT2038	1999	2001
Mathematics 20b	5	MAT2040	1999	2001
Mathematics 30	5	MAT3038	2000	2002
Pure				
Mathematics 10	5	MAT1037	N/A	1998
Mathematics 10b	3	MAT1039	N/A	1998
Mathematics 20	5	MAT2037	N/A	1999
Mathematics 20b	5	MAT2039	N/A	1999
Mathematics 30	5	MAT3037	N/A	2000

Print copies of the 1998 interim programs of study are available for purchase from the Learning Resources Distributing Centre or can be viewed and downloaded at <http://ednet.edc.gov.ab.ca> under Students and Learning, Student Programs, Mathematics.

MATHEMATICS 30

A. PROGRAM RATIONALE AND PHILOSOPHY

To set goals and make informed choices, students need an array of thinking and problem-solving skills. Fundamental to this is an understanding of mathematical techniques and processes that will enable them to apply the basic skills necessary to address everyday mathematical situations, as well as acquire higher order skills in logical analysis and methods for making valid inferences.

A knowledge of mathematics is essential for a well educated citizenry. However, the need for and use of mathematics in the life of the average citizen is changing. **Emphasis has shifted from the memorization of mathematical formulas and algorithms toward a more dynamic view of mathematics as a precise language, used to reason, interpret and explore.** There is still a need for the logical development of concepts and skills as a basis for the appropriate use of mathematical information to solve problems. The more traditional problem-solving techniques, combined with such techniques as estimation and simulation, and incorporated with modern technology, are the tools with which mathematical problems are solved.

Change in the way in which mathematics is used is necessitating a concurrent change in the emphases of mathematics education. Students need an expanded list of fundamental concepts but will also need to understand the ideas that make up those concepts and how they are related. They also require familiarity with their applications. Most important, students must be able to solve problems, using the mathematical processes developed, and be confident in their ability to apply known mathematical skills and concepts in the acquisition of new mathematical knowledge. In addition, the ability of technology to provide quick and accurate computation and manipulation, to enhance conceptual understanding and to facilitate higher order thinking, should be recognized and used by students.

The majority of students who enter senior high school exhibit mainly concrete operational behaviours with regard to mathematics. Students are expected to acquire much abstract understanding in senior high school mathematics courses. The course content of the Senior High School Mathematics Program is cognitively appropriate for the students and should be presented in a way that is consistent with the students' ability to understand.

The Senior High School Mathematics Program includes the course sequences Mathematics 16–26, 14–24, 13–23–33, plus Mathematics 30 and Mathematics 31. Transfer by students among courses of different sequences is possible. The course sequences commensurate with differing abilities, interests and aspirations, are designed to enable students to have success in mathematics. As well, the mathematics program reflects the

changing needs of society, and provides students with the mathematical concepts, skills and attitudes necessary to cope with the challenges of the future.

Mathematics 30 is designed for students, with an interest and aptitude in mathematics, who are intending to pursue post-secondary studies at a university or in a mathematics-intensive program at a technical school or college. Mathematics 30 emphasizes the theoretical development of topics in algebra, geometry, trigonometry and statistics up to a level acceptable for entry into universities and other post-secondary institutions.

B. GENERAL LEARNER EXPECTATIONS

Students are expected to be mathematically literate at the conclusion of their senior high school mathematics education. **Mathematical literacy** refers to students' ability and inclination to manage the demands of their world through the use of mathematical concepts and procedures to communicate, reason and solve problems. More specifically, *students will be expected to:*

- have achieved understanding of the basic mathematical concepts, and developed the skills and attitudes needed to become responsible and contributing members of society
- apply basic mathematical skills and concepts in practical situations
- have developed the skills, concepts and attitudes that will ensure success in the mathematical situations that occur in future educational endeavours, employment and everyday life
- have developed the skills, concepts and attitudes that will enable the acquisition of mathematical knowledge beyond the conclusion of secondary education
- have developed critical and creative thinking skills
- be able to communicate mathematical ideas effectively
- understand how mathematics can be used to investigate, interpret and make decisions in human affairs
- understand how mathematics can be used in the analysis of natural phenomena
- understand the connections and interplay among various mathematical concepts and between mathematics and other disciplines
- understand and appreciate the positive contributions of mathematics, as a science and as an art, to civilization and culture.

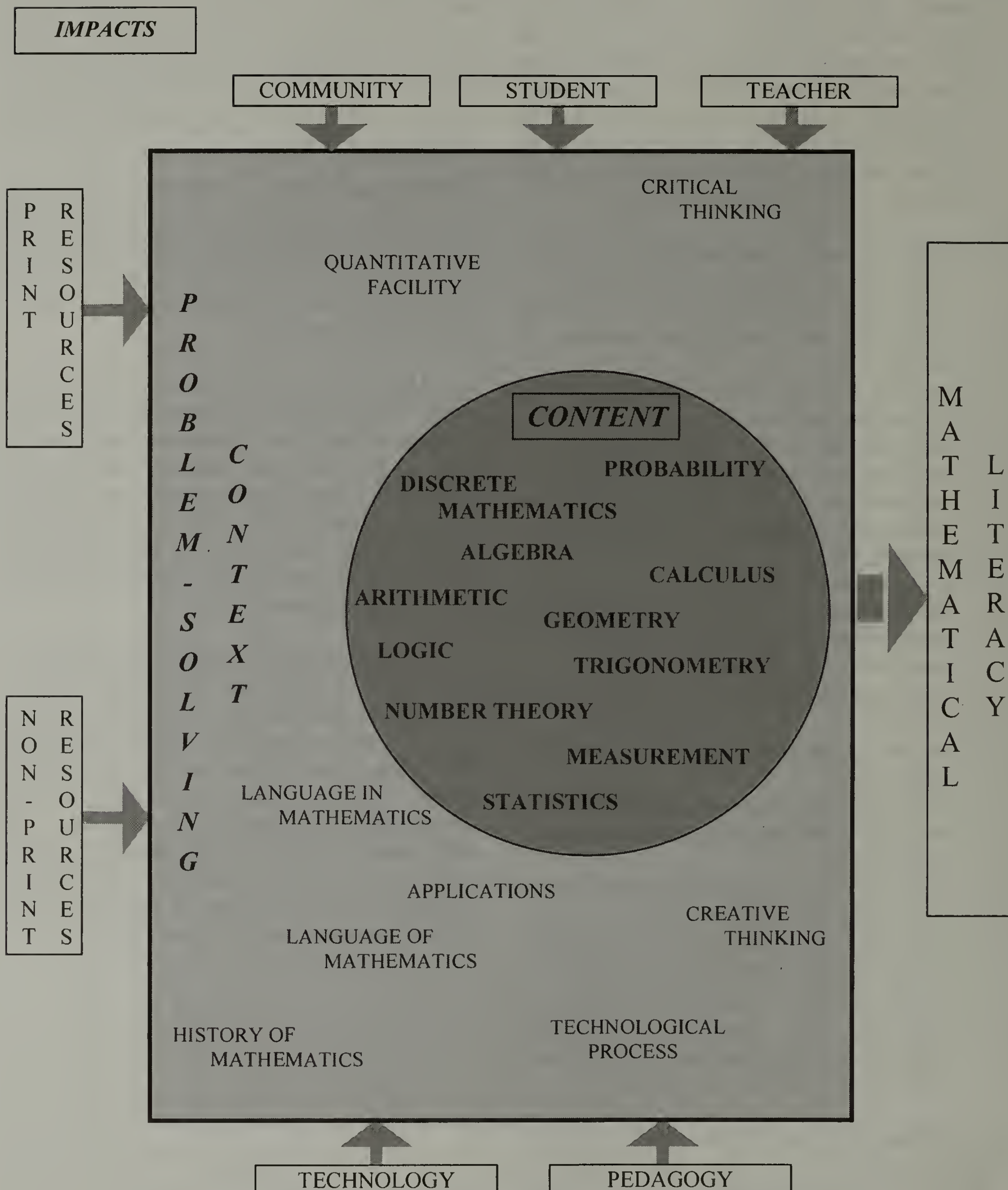
A General Model for Mathematical Literacy for Senior High School Programs, which outlines the factors that affect what and how students learn as they become mathematically literate, is presented on the following page. The model is fluid in that the content can be learned in a problem-solving context that engages any of a number of vehicles as the learning focus. At the same time, the students involved in the learning situation are affected in what and how they learn by forces that have impact on them.

The **Content** of the Senior High School Mathematics Program is the body of knowledge that is to be acquired by students. In the various senior high school mathematics courses, it is made up of topics that can be categorized into one or more of the listed strands.

In each course in the Senior High School Mathematics Program, students will focus on problem solving. The **Problem-solving Context** refers to the instruction emphases within which the specific content expectations can be acquired. The various entries indicated in the model suggest processes that belong to the problem-solving context and may be used by students as vehicles for learning the content.

The **Impacts** on the problem-solving context are those skills, attitudes and experiences that are possessed by the students and teachers involved, as well as the resources they may use throughout the learning process. They include the influence exerted by the culture and beliefs of the community as reflected by the school. The effectiveness of the context in enabling a student to acquire the content is dependent on the skillful management by the teacher of those items that have an impact on a student's learning.

A General Model for Mathematical Literacy for Senior High School Programs



C. SPECIFIC LEARNER EXPECTATIONS

PROGRAM ORGANIZATION

The major part of the content of each senior high school mathematics course consists of topics required of all students who take the course. The **required content** comprises 80 per cent of the course and contains the concepts, skills and attitudes that all students are expected to acquire. As well, the required portion of all courses includes specific expectations for problem solving and the use of technology.

Each course includes a compulsory component comprising 20 per cent of the course, made up of **elective material** that is consistent with the content and expectations of the required component. **The elective material provides for enrichment, remediation, or innovative or experimental presentations or activities. It is not intended to provide acceleration or advanced placement.** However, horizontal enrichment and extension is appropriate and students should have access to elective material that serves their individual needs and interests.

Evaluation of students in the Senior High School Mathematics Program will involve assessment of the level of achievement of all **of the learner expectations, including concepts, skills and attitudes, as well as problem-solving and technological expectations.** For more information regarding evaluation, consult the *Teacher Resource Manual for Senior High Mathematics*.

PROGRAM STRUCTURE

At the beginning of each course is a list of **attitude** expectations. These attitudes embody a mathematical attitude or frame of mind for a student to view the world. The attitude expectations should be woven into the fabric of the entire course.

Following this are the **problem-solving** expectations that outline a variety of procedures, strategies, skills and checking techniques for solving problems. Because a major purpose for studying mathematics is to learn to solve problems, problem-solving expectations occur throughout all areas of the specific learner expectations. Students must have the background skills and knowledge necessary to achieve these expectations successfully, using problem-solving techniques.

The units of the course are broken into a number of concepts. Each unit begins with an **overview** of the concepts and skills included in the unit. This indicates reasons why the unit is being studied and how these particular concepts and skills fit into the development of major mathematical concepts.

A **concept** is an abstract or general idea about specific instances that have common properties or an identifiable relationship to one another. The concepts are presented as mathematical definitions or theorems or as statements of mathematical ideas or abstractions.

Supporting each concept are a number of skills. **Skills** are intellectual or physical capabilities that will be developed in the context of the particular concept.

Skills specifically related to the use of **technology** identify areas in which scientific calculators and/or computer technology are applied by students as tools to be used for calculations, manipulation or graphing, or to aid in the analysis of problems. Technological expectations are defined explicitly throughout the learner expectations. In many cases, a particular technology is indicated for investigation or analysis. It is in these situations that the use of technology enables students to engage in critical and creative thinking and problem solving.

Students will be expected to learn how and when to use technology and have a demonstrated proficiency in **estimation** and **mental arithmetic**. To use technology effectively, they must be able

to judge the reasonableness of an answer and understand the importance of making a judgment about the result of a calculation.

The words verify and prove appear throughout the learner expectations. For the purposes of the Senior High School Mathematics Program, they are interpreted as:

- Verify – to substantiate the validity of an operation, solution, formula or theorem through the use of examples that may or may not be generalized
- Prove – to substantiate the validity of an operation, solution, formula or theorem in general and to provide logical arguments for each step in the process.

Attitudes

1. *Students will be expected to* demonstrate an attitude associated with mathematical literacy. In particular, students will be expected to:

   1.1 be confident in their mathematical knowledge and in their ability to acquire new knowledge
   1.2 demonstrate persistence, resolve, flexibility and ingenuity in finding the solution to problems
   1.3 develop intellectual curiosity and openness to new ideas, insights and change in the pursuit of mathematical knowledge
   1.4 exhibit an attitude of curiosity and spontaneity, and appreciate creativity and innovation in representing situations mathematically
   1.5 be critical and constructive in approaching new ideas and new processes
   1.6 be aware of the importance of communication skills in mathematics
   1.7 appreciate the usefulness of computational competence, mathematical processes and problem-solving skills that are used in the decision-making and modelling processes in our society
   1.8 appreciate the contributions of mathematics to our culture and civilization.

Problem Solving

1. *Students will be expected to* demonstrate an understanding of the variety of procedures that can be used to understand problems. In particular, students will be expected to:

   1.1 read the problem thoroughly
   1.2 identify and clarify key components
   1.3 restate the problem, using familiar terms
   1.4 evaluate the given information as to sufficiency and relevancy
   1.5 interpret pictures, charts and graphs
   1.6 determine hidden assumptions
   1.7 ask relevant questions
   1.8 identify given, needed and wanted information
   1.9 diagram or model the problem situation
   1.10 use suitable notation
   1.11 determine valid inferences
   1.12 simulate a problem situation
   1.13 formulate situations into identifiable problems.

2. *Students will be expected to* develop a variety of strategies for use in the solution of mathematical problems. In particular, students will be expected to:

    2.1 conduct an investigation
    2.2 use estimation and approximation
    2.3 develop equations or use formulas
    2.4 use flow charts
    2.5 make lists and charts
    2.6 look for patterns
    2.7 work backward
    2.8 break the problem into smaller parts
    2.9 look for a simpler or related problem
    2.10 make diagrams or models
    2.11 use manipulatives
    2.12 choose and sequence a series of mathematical operations
    2.13 sketch the graph of a problem situation
    2.14 establish procedures to gather and organize data
    2.15 apply empirical or inductive processes
    2.16 use geometric construction and measurement techniques
    2.17 make and test a conjecture.

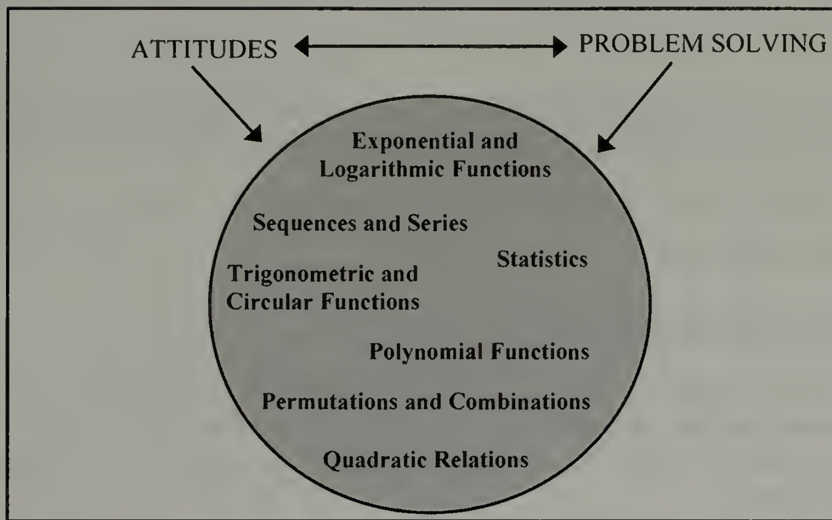
3. *Students will be expected to* develop a variety of skills that can be used to carry out the plan for the solution of a problem. In particular, students will be expected to:

    3.1 apply selected strategies
    3.2 present ideas clearly
    3.3 document the solution process
    3.4 use appropriate group behaviours
    3.5 use scientific graphing calculators and/or computers
    3.6 evaluate problem-solving strategies for effectiveness
    3.7 alter or abandon non-productive strategies
    3.8 search for additional information
    3.9 ask questions
    3.10 be open to inspirations, intuitions and "bright ideas".

4. *Students will be expected to* employ a variety of skills to help them look back over the solution of a problem. In particular, students will be expected to:

    4.1 determine the reasonableness of an answer
    4.2 explain the solution in oral or written form
    4.3 consider the possibility of additional solutions
    4.4 search for other strategies and processes of solution
    4.5 create and solve similar problems
    4.6 note the characteristics that will be identifiable in similar problems
    4.7 make a generalization
    4.8 examine the assumptions made and simplifications and modifications used for accuracy, effectiveness and efficiency.

MATHEMATICS 30 PROGRAM STRUCTURE



POLYNOMIAL FUNCTIONS

Overview

Much of the study of high school algebra is to provide the student with the ability to analyze general functions. For most high school students the study of polynomial functions is in many ways the culmination of their study of algebra. They should understand that algebra provides a means of operating with concepts at an abstract level and a process that can foster generalizations and insights beyond the original context.

The students' study of polynomial functions should not focus on developing mere manipulative facility but, rather, should emphasize conceptual understanding, coming to understand algebra as a means of representing general cases and a problem-solving tool. Emphasis should be on interpreting the graphs of functions, exploring the properties of graphs and determining how these properties relate to the forms of the corresponding equations.

Students should be aware that polynomial functions are very useful for describing relations among variables in a vast array of real-world situations. For example, analysis of polynomial functions frequently arises in the management sciences for examining cost, revenue and profit in the production and sale of goods. The use of computer technology and the methods associated with this technology, combined with a conceptual understanding of polynomial functions, enables students to gain powerful techniques for the analysis of complex functions.

The analysis of polynomial functions is one of the underpinnings to the study of calculus. The students' ability to visualize the graph of the function and to find the zero of the function are some of the ingredients in understanding calculus.

Learner Expectations

1. *Students will be expected to* demonstrate an understanding that a polynomial function is a function of the form $f(x) = a_n x^n + a_{n-1} x^{n-1} + \ldots a_1 x + a_0$ where $a_0, a_1 \cdots a_n$ are real numbers and $n \in N$.

2. *Students will be expected to* demonstrate an understanding that a polynomial function can be graphed on a Cartesian plane and that such graphs will have particular characteristics depending on the function.

   Students will be expected to:

   2.1 sketch the graphs of integral polynomial functions

   2.1.1 draw the graphs of integral polynomial functions using calculators or computers
   2.1.2 investigate the characteristics of the graphs of polynomial functions of different degrees and determine the effects of a multiplicity of zeros on the graphs of polynomial functions
   2.1.3 find approximations for the zeros of integral polynomial functions using calculators or computers
   2.1.4 analyze points on the graphs of polynomial functions using calculators or computers
   2.1.5 solve problems that can be represented by polynomial functions.

3. *Students will be expected to* demonstrate an understanding that many polynomial functions can have the same zeros.

   Students will be expected to:

   3.1 derive an equation of an integral polynomial function given its zeros
   3.2 derive the equation of an integral polynomial function given its zeros and an ordered pair that satisfies it

   3.2.1 find the equation of a polynomial function given its zeros and any other information that will uniquely define it.

4. *Students will be expected to* demonstrate an understanding of the following form of the division algorithm for polynomials: If any polynomial $P(x)$ is divided by a binomial of the form $(x - a)$ (called $D(x)$), the result will be a polynomial quotient $Q(x)$ and a remainder R.

   Students will be expected to:

   4.1 divide integral polynomial functions in one variable by a binomial
   4.2 write the division operation on a polynomial function by a binomial in the form of the Division Algorithm: $P(x) = D(x)Q(x) + R$.

5. *Students will be expected to* demonstrate an understanding that when a polynomial $P(x)$ is divided by a binomial of the form $(x - a)$, the remainder R is equal to $P(a)$ (Remainder Theorem).

Students will be expected to:

5.1 use the Remainder Theorem to evaluate polynomial functions for rational values of the variable

5.1.1 prove the Remainder Theorem

5.1.2 use the Remainder Theorem to prove that if a number a is a zero of a polynomial function $P(x)$ then $(x - a)$ will be a factor of $P(x)$ (Factor Theorem)

5.2 use the Factor Theorem to factor an integral polynomial function completely and to determine all of its real zeros

5.2.1 use a technology to factor polynomial functions

5.2.2 recognize that all rational zeros of a polynomial function will be of the form p/q, where p is a factor of a_0 and q is a factor of a_n.

TRIGONOMETRIC AND CIRCULAR FUNCTIONS

Overview

Trigonometry is not only an important and powerful tool for science and engineering, but is also esthetically attractive for many students because of its regularity and symmetry. The study of trigonometry in Mathematics 30 builds on the understanding of trigonometric ratios and how to use these ratios to solve real-world problems, and on the study of functions. In Mathematics 30, the ratios of right-angle trigonometry are generalized to both trigonometric and circular functions. Understanding of these functions and the connections between geometry and algebra are important in the future development of such topics as matrix representations of rotations, direction angles of vectors, polar coordinates and trigonometric representations of complex numbers. The trigonometric and circular functions are mathematical models for many periodic real-world phenomena, such as uniform circular motion, temperature changes, biorhythms, sound waves and tide variation.

Learner Expectations

1. *Students will be expected to* demonstrate an understanding that the radian measure of an angle is the ratio of the arc it subtends to the radius of a circle in which it is a central angle, and that one radian is the measure of a central angle subtended in a circle by an arc whose length is equal to the radius of the circle.

Students will be expected to:

1.1 identify the radian measure of a central angle in a circle

1.2 convert angle measurements between degree and radian measure and vice versa

1.3 determine the exact values of the trigonometric ratios for angles coterminal with $\frac{n\pi}{6}, \frac{n\pi}{4}, \frac{n\pi}{3}, \frac{n\pi}{2}$, and $n\pi; n \in I$.

2. *Students will be expected to* demonstrate an understanding that identities are statements of equality that are true for all values of the variable and that trigonometric identities are equations that express relations among trigonometric functions that are valid for all values of the variables for which the functions are defined.

   Students will be expected to:

   2.1 use the following fundamental trigonometric identities:

   Reciprocal Identities

   $$\frac{1}{\sin a} = \csc a$$

   $$\frac{1}{\cos a} = \sec a$$

   $$\frac{1}{\tan a} = \cot a$$

   Quotient Identities

   $$\frac{\sin a}{\cos a} = \tan a$$

   $$\frac{\cos a}{\sin a} = \cot a$$

   Pythagorean Identities

   $$\sin^2 a + \cos^2 a = 1$$
   $$\tan^2 a + 1 = \sec^2 a$$
   $$\cot^2 a + 1 = \csc^2 a$$

   2.1.1 derive the quotient and Pythagorean identities using logical processes
   2.1.2 use the fundamental trigonometric identities to simplify, evaluate and prove trigonometric expressions involving identities

   2.2 use the addition and subtraction identities (formulas):
   $\cos(a \pm b) = \cos a \cos b \mp \sin a \sin b$
   $\sin(a \pm b) = \sin a \cos b \pm \cos a \sin b$.

3. *Students will be expected to* demonstrate an understanding that trigonometric functions can be graphed on a Cartesian plane.

   Students will be expected to:

   3.1 graph the following forms of the sine, cosine and tangent functions:
   $y = a \sin [b(\theta + c)] + d$
   $y = a \cos [b(\theta + c)] + d$
   $y = \tan \theta$

3.1.1 use calculators or computers to draw and analyze the graphs of trigonometric functions

3.1.2 investigate the effects of the parameters a, b, c and d on the graphs of trigonometric functions using calculators or computers

3.1.3 state the domain and range of all the trigonometric functions.

4. *Students will be expected to* demonstrate an understanding of the methods used to solve trigonometric equations.

   Students will be expected to:

   4.1 solve first and second degree trigonometric equations involving multiples of angles on the domain $0 \le \theta < 2\pi$

   4.1.1 use calculators or computers to solve trigonometric equations by evaluating the graphs of trigonometric functions.

   4.2 demonstrate the relationship between the root of a trigonometric equation and the graph of the corresponding function.

STATISTICS

Overview

One form of data that is often encountered is that which has a normal distribution. Normally distributed data has particular interest to statisticians who wish to make predictions about a population based upon known data.

Learner Expectations

1. *Students will be expected to* demonstrate an understanding that data can be distributed normally, and that a normal distribution has particular characteristics that can be used to describe and analyze many situations.

   Students will be expected to:

   1.1 find and interpret the mean and standard deviation of a set of normally distributed data

   1.1.1 use calculators or computers to calculate the mean and standard deviation of sets of normally distributed data

   1.2 apply the characteristics of a normal distribution

   1.2.1 solve problems involving data that are normally distributed

   1.3 find and apply the standard normal curve and the z-scores of data that are normally distributed

   1.3.1 apply z-scores to solve problems involving probability distributions.

QUADRATIC RELATIONS

Overview

The study of quadratic relations connects several topics from the high school mathematics program. The topics of coordinate geometry and algebra are linked to the analysis of relations and the resulting graphs of the locus of these relations. Because there are a number of practical phenomena that can be described in terms of quadratic relations it is possible for students to see the connection between real-world applications and theoretical representations. Since all conic sections can be defined as the locus of a point such that the ratio of its distance from a fixed point and a fixed line is constant and each of the four conics can be generated by altering this ratio, the study of quadratic relations provides the student with the opportunity to analyze a complex mathematical relation to determine common properties and structures.

Learner Expectations

1. *Students will be expected to* demonstrate an understanding of the physical properties of the conic sections with respect to the intersection of a plane and a cone.

   Students will be expected to:

   1.1 describe the conic section formed by the intersection of a plane and a cone

   1.1.1 identify the point at which each of the conics becomes degenerate.

2. *Students will be expected to* demonstrate an understanding of the general quadratic relation $Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$ where $B = 0$ as the algebraic representation of any conic section with an axis of symmetry parallel to one of the coordinate axes.

   Students will be expected to:

   2.1 describe the conics that would be generated by various combinations of values for the numerical coefficients

   2.1.1 investigate and describe the effects of the numerical coefficients on the graphs of quadratic relations, using calculators or computers.

3. *Students will be expected to* demonstrate an understanding of the effects of the numerical coefficients in the general quadratic relation $Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$ where $B = 0$ on the curves of the resulting conics.

   Students will be expected to:

   3.1 analyze the graphs of ellipses, parabolas, and hyperbolas, given their equations

   3.1.1 use calculators or computers to draw the graphs of ellipses, parabolas and hyperbolas
   3.1.2 recognize which conditions are required for an ellipse to become a circle
   3.1.3 investigate and describe the effects of the numerical coefficient on the orientation, size and shape of the graph.

4. *Students will be expected to* demonstrate an understanding that a locus is a system of points that satisfies a given condition.

   Students will be expected to:

   4.1 recognize that each conic can be described as a locus of points

      4.1.1 use the locus definition to verify the equations that describe the conics
      4.1.2 solve problems that involve analyzing and determining the characteristics of a body that follows a conical path
      4.1.3 solve problems that involve analyzing and determining the characteristics of a conical surface.

5. *Students will be expected to* demonstrate an understanding that any conic can be described as the locus of points, such that the ratio of the distance between any point and a fixed point to the distance between the same point and a fixed line is a constant. This ratio is called eccentricity.

EXPONENTIAL AND LOGARITHMIC FUNCTIONS

Overview

The study of exponential and logarithmic functions is an application of the general study of functions from Mathematics 20. For example, the logarithmic and exponential functions provide a good example of inverse functions. In this unit of study, students have further opportunity to understand the connections of functions to real-world phenomena, by using certain phenomena as models of functions in symbolic form and then graphing the functions. The study of the operations in logarithms and logarithmic equations provides the student with the opportunity to understand how a mathematics system operates and realize that the rules that govern properties and solution of equations apply to the system as a whole.

Learner Expectations

1. *Students will be expected to* demonstrate an understanding that an exponential function is one in which the variable appears in the exponent.

   Students will be expected to:

   1.1 sketch the graph of exponential functions of the form $y = a^x$, $a > 0$
   1.2 use the graphs of exponential functions to estimate the values of roots and powers

      1.2.1 draw and analyze the graphs of exponential functions using calculators or computers
      1.2.2 determine the domain and range of the exponential functions

   1.3 solve and verify exponential equations.

2. *Students will be expected to* demonstrate an understanding that many real-world phenomena exhibit exponential properties.

   Students will be expected to:

   2.1 recognize exponential functions describing situations involving exponential growth and decay

      2.1.1 solve problems involving exponential growth and decay.

3. *Students will be expected to* demonstrate an understanding of the characteristics and applications of logarithmic functions.

   Students will be expected to:

   3.1 draw the graphs of logarithmic functions as the inverses of exponential functions
   3.2 use the graphs of logarithmic functions to find the values of one of the variables, given the other variable

      3.2.1 draw and analyze the graphs of logarithmic functions using calculators or computers
      3.2.2 determine the domain and range of the logarithmic functions

   3.3 convert functions from exponential form to logarithmic form and vice versa.

4. *Students will be expected to* demonstrate an understanding that operations with logarithms are subject to basic properties and laws.

   Students will be expected to:

   4.1 apply the following laws and properties of logarithms:

$$\log_a(mn) = \log_a m + \log_a n$$
$$\log_a\left(\frac{m}{n}\right) = \log_a m - \log_a n$$
$$\log_a(m^n) = n \log_a m$$

      4.1.1 evaluate logarithmic expressions using calculators and computers

   4.2 solve and verify logarithmic equations

      4.2.1 solve and verify logarithmic equations using calculators or computers.

5. *Students will be expected to* demonstrate an understanding that a logarithm with a base of 10 is a common logarithm.

   Students will be expected to:

   5.1 solve logarithmic equations and evaluate logarithmic expressions using common logarithms.

6. *Students will be expected to* demonstrate an understanding that many phenomena exhibit characteristics that can be described using logarithmic functions.

Students will be expected to:

6.1 recognize logarithmic functions that describe situations that have logarithmic characteristics

6.1.1 solve problems that exhibit logarithmic properties by developing and solving logarithmic equations.

PERMUTATIONS AND COMBINATIONS

Overview

An understanding of permutations and combinations is becoming increasingly important for processing, analyzing and communicating information. One example of the use of permutations is in determining security codes for computers. The ability of computers to try large numbers of different permutations of numerals rapidly makes the design of computer security systems much more difficult. Whole new branches of mathematics are being developed to deal with problems of this nature. Understanding of permutations and combinations is important to building an understanding of formal concepts of theoretical probability and to be able to interpret and judge the validity of statistical claims in view of underlying probabilistic assumptions. In determining the probability of an event, the number of ways of an event happening must be compared to the total number of possible outcomes. This counting of alternatives cannot always be easily determined by simple enumeration. The study of permutations and combinations provides methods for counting under complicated conditions.

Emphasis in this unit is on the development of students' ability to solve problems, using combinatorial analysis as opposed to the simple application of analytic formulas for permutations and combinations. In Mathematics 20, students learned about probability and how to find the probability that two events would occur. Students in Mathematics 20 were also expected to be able to design and carry out simulations.

Learner Expectations

1. *Students will be expected to* demonstrate an understanding of the Fundamental Counting Principle.

Students will be expected to:

1.1 calculate the total number of ways that a multiple of tasks can be conducted if each task can be performed in a multiple of ways

1.1.1 solve problems that involve the use of the fundamental counting principle.

2. *Students will be expected to* demonstrate an understanding that a permutation is an arrangement in which the order is important.

   Students will be expected to:

   2.1 calculate the number of permutations there are of n things taken r at a time by applying the following formula: ${}_nP_r = \dfrac{n!}{(n-r)!}$

   2.1.1 calculate ${}_nP_r$ using calculators and computers
   2.1.2 solve problems involving linear permutations, permutations with repetitions, circular and ring permutations
   2.1.3 solve probability questions that involve the use of permutations.

3. *Students will be expected to* demonstrate an understanding that a combination is an arrangement in which the order is not important.

   Students will be expected to:

   3.1 calculate the number of combinations there are of n things taken r at a time by applying the following formula: ${}_nC_r = \dfrac{n!}{r!(n-r)!}$

   3.1.1 calculate ${}_nC_r$ using a calculator or computer
   3.1.2 solve problems including probability problems that involve the use of combinations.

4. *Students will be expected to* demonstrate an understanding that the numerical coefficients of the terms in a binomial expansion can be determined using the Binomial Theorem.

   Students will be expected to:

   4.1 expand binomials of the form $(x + a)^n$, $n \in W$ using the Binomial Theorem
   4.2 relate the numerical coefficients in a binomial expansion to the terms of Pascal's Triangle and vice versa.

SEQUENCES AND SERIES

Overview

The non-material world of information processing requires the use of discrete or discontinuous mathematics. Computers are essentially finite, discrete machines, and thus it is essential for students to understand topics from discrete mathematics such as sequences and series to be able to solve problems using computer methods. In studying sequences and series, students should come to understand the power of sequences and series to describe recurrence relations; that is, formulas expressing each term as a function of one or more of the previous terms. Students should understand the role of recurrence formulas for solving enumeration problems since these can be translated easily to computer programs to obtain solutions. Students should use difference-equation techniques to express recurrence relations in closed form; that is, the n^{th} term written as a function of n.

Recurrence relations can be used to model real-world phenomena. For example, the terms in the Fibonacci sequence occur surprisingly frequently in nature and the analysis of these arrangements provides an ideal setting for integrating the study of mathematics and botany.

The study of finite sequences and series leads to consideration of the corresponding infinite cases and concepts associated with limiting processes. Although the study of these concepts is beyond the consideration of this course, an understanding of the concepts contained here will contribute to the meaningful development of the concepts associated with calculus.

Learner Expectations

1. *Students will be expected to* demonstrate an understanding that a sequence is a set of quantities determined by a rule (function) whose domain is the natural numbers and whose range is the terms of the sequence.

   Students will be expected to:

   1.1 recognize finite and infinite sequences
   1.2 write the terms of a sequence given the function that defines it
   1.3 write the terms of a sequence given its recursive definition
   1.4 determine the functions that describes simple sequences.

2. *Students will be expected to* demonstrate an understanding that a series is the sum of the terms of a sequence.

   Students will be expected to:

   2.1 expand a series that is given in sigma notation.

3. *Students will be expected to* demonstrate an understanding that arithmetic sequences are such that each term is equal to the sum of the preceding term and a constant and that an arithmetic series is the indicated sum of the terms of an arithmetic sequence.

   Students will be expected to:

   3.1 apply the general term formula of arithmetic sequences, $t_n = a + (n - 1)d$

      3.1.1 solve problems involving the use and application of the general term formula for arithmetic sequences

   3.2 apply the sum formula of arithmetic series, $S_n = \frac{n}{2}(a + t_n)$; $S_n = \frac{n}{2}[2a + (n - 1)d]$

      3.2.1 solve problems involving the use and application of the sum formula for arithmetic series
      3.2.2 use technology where applicable.

4. *Students will be expected to* demonstrate an understanding that geometric sequences are such that each term is equal to the product of the preceding term and a constant and that a geometric series is the indicated sum of the terms of a geometric sequence.

Students will be expected to:

4.1 apply the general term formula of geometric sequences, $t_n = ar^{n-1}$

4.1.1 solve problems involving the use and application of the general term formula for geometric sequences

4.2 apply the sum formula of geometric series, $S_n = \dfrac{a(r^n - 1)}{r - 1}, r \neq 1; S_n = \dfrac{rt_n - a}{r - 1}, r \neq 1$

4.2.1 solve problems involving the use and application of the sum formula for geometric series

4.2.2 use technology where applicable.

SCIENCE

CONTENTS

★ Copies of the interim Science 10 and Science 20–30 programs of study, dated June 30, 1995, are available for purchase from the Learning Resources Distributing Centre.

Internet

The Science Vision Statement, and all the science programs of study, are available for viewing and downloading at <http://ednet.edc.gov.ab.ca> under Students and Learning, Student Programs, Science.

BIOLOGY 20–30

A. PROGRAM OVERVIEW

RATIONALE AND PHILOSOPHY

Biology is the study of life and living systems from the molecular level to the biosphere. Through the study of biology, learners are given an opportunity to explore and understand the natural world and to become aware of the profound influence of biology in their lives. Learning is facilitated by relating the study of biology to what the learners already know, deem personally useful and consider relevant. Learning proceeds best when it originates from a base of concrete experiences presenting an authentic view of science in the context of biology. In Biology 20–30, students learn biology in relevant contexts and engage in meaningful activities. This facilitates the transfer of knowledge to new contexts. Students are encouraged to participate in lifelong learning about biology and to appreciate it as a scientific endeavour with practical impact on their own lives and on society as a whole.

Biology, as with all sciences, is an experimental discipline requiring creativity and imagination. Methods of inquiry characterize its study. In Biology 20–30, students further develop their ability to ask questions, investigate and experiment; to gather, analyze and assess scientific information; and to test scientific laws and principles and their applications. In the process, students exercise their creativity and develop their critical thinking skills. Through experimentation, and problem-solving activities that include the integration of technology and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The Biology 20–30 program places students at the centre. Students are active learners and will assume increased responsibility for their learning as they work through the program. A thorough study of biology is required to give students an understanding that encourages them to make appropriate applications of scientific concepts to their daily lives and prepares them for future studies in biology. Students are expected to participate actively in their own learning. An emphasis on the key concepts and principles of biology provides students with a more unified view of the sciences and a greater awareness of the connections among them.

These science learnings will take varying amounts of time to acquire, depending on the individual learning styles and abilities of students. While each course is designed for approximately 125 hours, instructional time can be modified to meet the individual needs of students. Some students will require more than 125 hours, while others will require less.

GOALS

The major goals of the Biology 20–30 program are:

- to develop in students an understanding of the interconnecting ideas and principles that transcend and unify the natural science disciplines
- to provide students with an enhanced understanding of the scientific world view, inquiry and enterprise
- to help students attain the level of scientific awareness essential for all citizens in a scientifically literate society
- to help students make informed decisions about further studies and careers in science
- to provide students with opportunities for acquiring knowledge, skills and attitudes that contribute to personal development.

Biology 20–30 is an academic program that helps students better understand and apply fundamental concepts and skills. The focus is on helping students understand the biology principles behind the natural events they experience and the technology they use in their daily lives. The program encourages enthusiasm for the scientific enterprise and develops positive attitudes about biology as an interesting human activity with personal meaning. It develops in students the knowledge, skills and attitudes to help them become capable of, and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities.

B. LEARNER EXPECTATIONS

GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for the specific learner expectations covered in section C. The general learner expectations are developed in two categories: *program* expectations and *course* expectations.

PROGRAM GENERAL LEARNER EXPECTATIONS

The *program* general learner expectations are broad statements of science attitudes, knowledge, skills and science, technology and society (STS) connections that students are expected to achieve in all of the senior high school science programs. These *program* general learner expectations are further refined through the *course* general learner expectations and then developed in specific detail through the study of individual units in each of Biology 20 and Biology 30. All expectations follow a progression from Science 10 through to Biology 30, and though listed separately, are meant to be developed in conjunction with one another, within a context.

ATTITUDES

Students will be encouraged to develop:

- enthusiasm for, and a continuing interest in, science
- affective attributes of scientists at work; such as, respect for evidence, tolerance of uncertainty, intellectual honesty, creativity, perseverance, cooperation, curiosity and a desire to understand
- positive attitudes toward scientific and technological skills involving process skills, mathematics, and problem solving
- open-mindedness and respect for the points of view of others
- sensitivity to the living and nonliving environment
- appreciation of the roles of science and technology in our understanding of the natural world.

KNOWLEDGE

Science Themes

Students will be expected to demonstrate an understanding of themes that transcend the discipline boundaries, and show the unity among the natural sciences, including:

- Change: how all natural entities are modified over time, how the direction of change might be predicted and, in some instances, how change can be controlled
- Diversity: the array of living and nonliving forms of matter and the procedures used to understand, classify and distinguish those forms on the basis of recurring patterns
- Energy: the capacity for doing work that drives much of what takes place in the Universe through its variety of interconvertible forms
- Equilibrium: the state in which opposing forces or processes balance in a static or dynamic way
- Matter: the constituent parts, and the variety of states of the material in the physical world
- Systems: the interrelated groups of things or events that can be defined by their boundaries and, in some instances, by their inputs and outputs.

SKILLS

Students will be expected to develop an ability to use thinking processes associated with the practice of science for understanding and exploring natural phenomena, problem solving and decision making. Students will also be expected to use teamwork, respect the points of view of others, make reasonable compromises, contribute ideas and effort, and lead when appropriate to achieve the best results. These processes involve many skills that are to be developed within the context of the program content.

Students will also be expected to be aware of the various technologies, including information technology, computer software and interfaces that can be used for collecting, organizing, analyzing and communicating data and information.

The skills framework presented here assumes that thinking processes often begin with an unresolved problem or issue, or an unanswered question. The problem, issue or question is usually defined and hypotheses formulated before information gathering can begin. At certain points in the process, the information needs to be organized and analyzed. Additional ideas may be generated—for example, by prediction or inference—and these new ideas, when incorporated into previous learning, can create a new knowledge structure. Eventually, an outcome, such as a solution, an answer or a decision is reached. Finally, criteria are established to judge ideas and information in order to assess both the problem-solving process and its outcomes.

The following skills are not intended to be developed sequentially or separately. Effective thinking is nonlinear and recursive. Students should be able to access skills and strategies flexibly; select and use skills, processes or technologies that are appropriate to the tasks; and monitor, modify or replace them with more effective strategies.

- Initiating and Planning
  - identify and clearly state the problem or issue to be investigated
  - differentiate between relevant and irrelevant data or information
  - assemble and record background information
  - identify all variables and controls
  - identify materials and apparatus required
  - formulate questions, hypotheses and/or predictions to guide research
  - design and/or describe a plan for research, or to solve a problem
  - prepare required observation charts or diagrams, and carry out preliminary calculations
- Collecting and Recording
  - carry out the procedure and modify, if necessary
  - organize and correctly use apparatus and materials to collect reliable data
  - observe, gather and record data or information accurately according to safety regulations; e.g., Workplace Hazardous Materials Information System (WHMIS), and environmental considerations
- Organizing and Communicating
  - organize and present data (themes, groups, tables, graphs, flow charts and Venn diagrams) in a concise and effective form
  - communicate data effectively, using mathematical and statistical calculations, where necessary
  - express measured and calculated quantities to the appropriate number of significant digits, using SI notation for all quantities
  - communicate findings of investigations in a clearly written report

- Analyzing
  - analyze data or information for trends, patterns, relationships, reliability and accuracy
  - identify and discuss sources of error and their affect on results
  - identify assumptions, attributes, biases, claims or reasons
  - identify main ideas
- Connecting, Synthesizing and Integrating
  - predict from data or information, and determine whether or not these data verify or falsify the hypothesis and/or prediction
  - formulate further, testable hypotheses supported by the knowledge and understanding generated
  - identify further problems or issues to be investigated
  - identify alternative courses of action, experimental designs, and solutions to problems for consideration
  - propose and explain interpretations or conclusions
  - develop theoretical explanations
  - relate the data or information to laws, principles, models or theories identified in background information
  - propose solutions to a problem being investigated
  - summarize and communicate findings
  - decide on a course of action
- Evaluating the Process or Outcomes
  - establish criteria to judge data or information
  - consider consequences and biases, assumptions and perspectives
  - identify limitations of the data or information, and interpretations or conclusions, as a result of the experimental/research/project/design process or method used
  - evaluate and suggest alternatives and consider improvements to the experimental technique and design, the decision-making or the problem-solving process
  - evaluate and assess ideas, information and alternatives

CONNECTIONS AMONG SCIENCE, TECHNOLOGY AND SOCIETY

Science, Technology and Society (STS)

Students will be expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationships among science, technology and society, including:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of processes or products based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

FURTHER READING

For a more detailed discussion on how to integrate thinking and research skills into the science classroom, refer to the publications: *Teaching Thinking: Enhancing Learning,* 1990 and *Focus on Research: A Guide to Developing Students' Research Skills,* 1990.

For further reading on integrating science, technology and society into the classroom, refer to the publication: *STS Science Education: Unifying the Goals of Science Education,* 1990.

COURSE GENERAL LEARNER EXPECTATIONS

The *course* general learner expectations are specific to each of Biology 20 and Biology 30 providing a bridge between the *program* general learner expectations and the specific learner expectations for each unit of study.

The attitudes expectations refer to those predispositions that are to be fostered in students. These expectations encompass attitudes toward science, the role of science and technology, and the contributions of science and technology toward society. The knowledge expectations are the major biology concepts in each course. The skills expectations refer to the thinking processes and abilities associated with the practice of science, including understanding and exploring natural phenomena, and problem solving. The connections among science, technology and society expectations focus on: the processes by which scientific knowledge is developed; the interrelationships among science, technology and society; and links each course to careers, everyday life and subsequent studies of biology.

Although itemized separately, the attitudes, knowledge, skills and STS connections are meant to be developed together within one or more contexts.

Biology 20–30

Attitudes

Students will be encouraged to:

- appreciate the role of empirical evidence and models in science, and accept the uncertainty in explanations and interpretations of observed phenomena
- value the curiosity, openness to new ideas, creativity, perseverance and cooperative hard work required of scientists, and strive to develop these same personal characteristics
- appreciate the role of science and technology in advancing our understanding of the natural world, be open-minded and respectful of other points of view when evaluating scientific information and its applications, and appreciate that the application of science and technology by humankind can have beneficial as well as harmful effects and can cause ethical dilemmas
- show a continuing interest in science, appreciate the need for computational competence, problem-solving and process skills when doing science, and value accuracy and honesty when communicating the results of problems and investigations
- appreciate the complexity of our planet and its diversity of ecosystems, value all organisms and the role they play, appreciate the relationship between humans and their natural environment, and take responsibility toward environmental use within the limits of sustainable development.

Biology 20

Students will be able to:

Knowledge

- explain how equilibrium in the biosphere is maintained by the flow of energy from the Sun through the chemical processes of photosynthesis and cellular respiration, and by the cycling of matter through the biogeochemical cycles; and describe the influence of human activities on the equilibrium of energy and matter exchange and atmospheric composition
- explain the role of structure, function and regulatory mechanisms of the digestive, respiratory, excretory and circulatory systems in energy and matter exchange; and describe blood cellular components, and explain the role of the immune system in protecting the human organism and maintaining internal equilibrium

- explain how solar energy and matter are converted by cellular photosynthetic processes to ATP or stored in organic compounds as potential chemical energy, and how this potential energy can be converted by cellular respiration to ATP; and describe the influence of oxygen, carbon dioxide and environmental toxins on these processes

- differentiate ecosystems on the basis of the energy and matter exchange of their biotic and abiotic components, by performing field studies on terrestrial and aquatic ecosystems; and explain, quantitatively and qualitatively, the trophic structure of ecosystems, using models, such as food webs, chains and pyramids

- list the direct and indirect evidence that supports the evolution of modern species from ancestral forms; and explain the theory of natural selection and how inherited variability within populations causes evolutionary change and speciation

- explain why populations are the basic components of an ecosystem; and describe the direct and indirect evidence of inherited and acquired variation in population gene pools, and explain the basis for the range of this variation found within individual species of a population

<u>Skills</u>

- perform investigations and tasks of their own and others' design that have a few variables and yield direct or indirect evidence; and provide explanations based upon scientific theories and concepts

- collect, verify and organize data into tables of their own design, and graphs and diagrams of others' design, using written and symbolic forms; and describe findings or relationships, using scientific vocabulary, notation, theories and models

- analyze and interpret data that yield straight- and curved-line graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and calculate slopes of, and areas under, straight-line graphs; and derive mathematical relationships among variables

- use mathematical language of ratio and proportion, simple equations, and unit analysis to solve single- and multi-step problems; and to communicate scientific relationships and concepts

<u>Connections Among Science, Technology and Society</u>

- apply cause and effect reasoning to formulate simple relationships for a given instance in which scientific evidence shapes or refutes a theory; and describe the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and explain the design and function of technological solutions to practical problems, using scientific principles; and relate the ways in which biology and technology advance one another, using appropriate and relevant examples

- explain for a given instance how science and technology are influenced and supported by society, and the responsibility of society, through biology and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Biology 20 to everyday life and to related and new concepts in subsequent studies of biology.

Biology 30

Students will be able to:

Knowledge

- describe the structure and explain the function of nervous and hormonal control systems that enable the human organism to maintain internal equilibrium among its systems while simultaneously interacting and maintaining equilibrium with the external environment; and explain the role of selected hormones in metabolism and homeostasis

- describe mitosis and the cell cycle; and compare mitosis with meiosis and explain the significance to a species of chromosome number reduction and crossing over during meiosis; and describe gametogenesis, fertilization, fetal development and reproductive technologies in humans; and compare and contrast alternation of generations in a range of vascular plants and animals

- describe the anatomy and physiology of single neurons in relation to the initiation, formation and transmission of electrochemical impulses; and explain how sensory receptors, such as the eye and ear, act as energy converters

- describe the anatomy of human reproductive systems; and explain the hormonal control and maintenance of reproductive systems in adults; and describe how sexually transmitted diseases interfere with system function; and describe and explain the physiological events in the fetus that result in the formation of male and female genitalia

- explain heredity; describe direct and indirect evidence for chromosomes, genes, alleles and the influence of crossing over and sex chromosomes, and explain the role of this evidence in formulating the principles of inheritance; and explain the molecular basis of inheritance by describing DNA structure, expression and mutation; and explain the significance of genomes to species and the influence of biotechnology on genes and genomes

- explain the significance of the Hardy–Weinberg equilibrium to gene pools, and the significance of gene pool change over time; and describe the chaos theory and explain and analyze, quantitatively, the factors and strategies that influence population growth

Skills

- perform and evaluate investigations and tasks of their own and others' design that have multiple variables and yield direct or indirect evidence; and provide explanations and interpretations, using scientific theories and concepts

- collect, verify and organize data into tables, graphs and diagrams of their own design, using written and symbolic forms; and describe findings or relationships and make predictions, using scientific vocabulary, notation, theories and models

- analyze, interpret and evaluate data that yield straight- and curved-lined graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and calculate slopes of, and areas under, straight-line graphs; and derive mathematical relationships among variables

- use mathematical language of ratio and proportion, equations, simple probability and unit analysis to solve single- and multi-step problems; and communicate scientific relationships and concepts

Connections Among Science, Technology and Society

- apply cause and effect reasoning to formulate relationships for a range of instances in which scientific evidence shapes or refutes a theory; and explain the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and evaluate the design and function of technological solutions to practical problems, using scientific principles or theories; and relate the ways in which biology and technology advance one another, using appropriate and relevant examples

- explain and evaluate for a given instance, and from a variety of given perspectives, how science and technology are influenced and supported by society; and assess the ability and responsibility of society, through biology and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Biology 30 to everyday life and to related and new concepts in post-secondary studies of biology.

SPECIFIC LEARNER EXPECTATIONS

LEARNING CYCLE

The specific learner expectations consist of the knowledge, skills and attitudes that are to be addressed in Biology 20–30. The use of the learning cycle allows students to progress, from:

- an introduction framing the lesson in an STS connection relevant to the lives of the learners, and makes connections between past and present learning experiences, as well as anticipates activities to focus students' thinking on the learning outcomes of the activity

TO

- the experiential exploration of new content that provides students with a common base of experiences within which they identify and develop key concepts, processes and skills

THROUGH

- a hypothesis-building phase where concepts are developed to describe a particular aspect of their experiential exploration, and opportunities are provided to communicate their conceptual understanding, or demonstrate their skills or behaviours

TO

- an elaboration phase that extends understanding of key concepts and allows further opportunities to practise desired skills and problem-solving strategies

TO

- an application phase where the hypotheses, vocabulary and patterns previously developed are applied to new situations and related to key concepts and principles of science

TO

- a final evaluation of the significance of the new learning in an STS context to assess their understanding and abilities, and provide opportunities for evaluation of student progress toward achieving the curriculum standards.

In Biology 20–30, students examine phenomena in a variety of topics to show the relationships among all the sciences. Wherever possible, examples should be framed in the context of the learners' own experiences to enable them to make the connections between scientific knowledge and the society around them, the technology that societies have developed, and the nature of science itself.

PROGRAM OVERVIEW

The Biology 20–30 program emphasizes the science themes: *change, diversity, energy, equilibrium*, *matter* and *systems* as they relate to biology. These themes provide a means of showing the connections among the units of study in both courses of the program, and provide a framework for students to learn how individual sections of the program relate to the big ideas of science.

In addition to developing a solid understanding of fundamental science concepts and principles, Biology 20–30 has the goal of educating students about the nature of science and technology, and the interaction between biology and technology. Students must be aware of the tremendous impact of biology and associated technology on society, but at the same time, they must be aware of the roles and limitations of the biological sciences, science in general, and of technology in problem solving in a societal context.

BIOLOGY 20

The major science themes developed in this course are *diversity, energy, equilibrium, matter* and *systems*.

The major concepts allow connections to be drawn among the four units of the course and among all eight units in the two courses in the program.

Biology 20 consists of four units of study:

Unit 1: The Biosphere
Unit 2: Energy Flows and Cellular Matter
Unit 3: Energy and Matter Exchange in Ecosystems
Unit 4: Energy and Matter Exchange by the Human Organism.

Unit 1 focuses on the dynamic *equilibria* that exist for *energy* and *matter* in the biosphere, and the *systems* that regulate those *equilibria*. In Unit 2, *energy* from the environment is traced through photosynthetic and cellular respiratory *systems* with the associated cycling of *matter* in the form of carbon. Unit 3 examines the *diversity* in characteristics of some of the *ecosystems* that make up the biosphere, and the interactions of the organisms mediating the flow of *energy* and *matter* through those *ecosystems*. The unit closes with a discussion of how organisms evolve to fill available niches in *ecosystems*. The particular case of the human organism *system* and its *energy* and *matter* exchanges with the environment is examined in Unit 4, along with its biotic interactions with pathogenic organisms and the maintenance of *equilibrium* with its environment.

BIOLOGY 30

The major science themes developed in this course are *change, diversity, equilibrium* and *systems*.

The major concepts allow connections to be drawn among the four units of the course and among all eight units in the two courses in the program.

Biology 30 consists of four units of study:

Unit 1: Systems Regulating Change in Human Organisms
Unit 2: Reproduction and Development
Unit 3: Cells, Chromosomes and DNA
Unit 4: Change in Populations and Communities.

Biology 30 expands upon the concepts and skills introduced in Science 10 and Biology 20. Unit 1 focuses on chemical and electrical *systems* that regulate body processes to maintain *equilibrium*, and the processes of reproduction and development as *systems* for bringing about *change* are examined in Unit 2. Both of these units use the human organism as a model system. The themes of *change* and *diversity* run through Unit 3 as the mechanisms for passing on genetic information and causing variation, and are examined for a range of organizational levels. Finally, Unit 4 looks at *change* as illustrated by the genetics of populations, at equilibrium in populations, and at the community *systems* in which populations exist.

BIOLOGY 20

UNIT 1
THE BIOSPHERE

OVERVIEW

Science Themes: *Energy, Equilibrium, Matter* and *Systems*

In Unit 1, students investigate the *matter* and *energy equilibrium* between photosynthetic activity and the cellular respiratory activity of living *systems*. The nature of water and other forms of *matter* as substrata for life is discussed during a survey of the hydrologic cycles and the biogeochemical cycles of several significant elements, and an examination of the roles of living *systems* in that cycling. The unit closes with a discussion of the impact of living *systems* on the *equilibrium* of atmospheric composition.

This unit builds on Science 10, Unit 1: Energy from the Sun, and Unit 2: Energy and Matter in Living Systems. It provides students with a foundation for the study of the nature of *energy* and *matter* flow at the cellular level in Unit 2, the *ecosystem* level in Unit 3, and the organism level in Unit 4.

The three **major concepts** developed in this unit are:

- the biosphere is maintained by a constant flow of *energy*
- the cycling of *matter* through the biosphere perpetuates its steady state *equilibrium*
- the balance of *energy* and *matter* exchange in the biosphere, as an open *system,* maintains its steady state *equilibrium.*

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities related to *energy* and *matter* research on the biosphere
- collecting and recording environmental data
- organizing and communicating research results
- connecting, synthesizing and integrating data or information, and interpretations related to the biosphere as a *system.*

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the complexity of our planet
- develop an awareness of one's personal role in the preservation of the environment
- develop a sense of responsibility toward use of our environment
- develop optimism about humankind's ability to learn to function within the limits of sustainable development
- develop an open-mindedness concerning the views and values of others
- develop an attitude of participation in planning and shaping the future
- develop an awareness of global issues and the contribution of local activity to the resolution of global problems.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. The biosphere is maintained by a constant flow of *energy*.	• most of the energy used in the biosphere comes from the Sun and is either stored or reradiated back into space, by extending from Science 10, Unit 1, the Sun's role in heating Earth, and by: • explaining how energy storage in the biosphere, as a system, can be visualized as a balance between photosynthetic and cellular respiratory activities • describing how stored biological energy in the biosphere, as a system, is eventually lost as heat; e.g., muscle heat generation, decomposition.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the biosphere is maintained by solar energy that flows through photosynthesis and respiration and is lost as heat; and by measuring and comparing solar energy variations; and performing experiments that demonstrate plant energy storage, within the context of:
• performing an experiment to demonstrate, quantitatively, solar energy storage by plants • measuring the amount of solar radiation in the local area, and comparing this with solar radiation data of other areas of the province and/or the country.	• evaluating the evidence for the influence of ice and snow on the storage of solar energy; i.e., albedo effect, hypothesizing about consequences of fluctuations for biological systems OR • explaining how metabolic heat release from harvested grain can be reduced by drying processes prior to grain storage by explaining the scientific principles involved in this technology OR • assessing the energy savings achieved in the overall requirements of large office buildings by using thermal energy recycling technologies to capture metabolic heat and the influence of the needs, interests and financial support of society in the development of these technologies OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The cycling of *matter* through the biosphere perpetuates its steady state *equilibrium.*	• specific chemical elements are cycled through the biotic and abiotic components of the biosphere, by extending from Science 10, Unit 1, the hydrologic cycle, and by: • summarizing and explaining the biogeochemical cycles for carbon, nitrogen and phosphorous • explaining how water is cycled through the biosphere along characteristic pathways • identifying the properties of water and explaining their relevance to the hydrologic cycle; e.g., freezing point, hydrogen bonding, specific heat, density.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that biosphere cycling of matter perpetuates its steady state; and by predicting and hypothesizing the human influence in these cycles; and by measuring and comparing precipitation and water movement; and designing matter exchange experiments with plants and animals, within the context of:
• predicting disruptions in nitrogen and phosphorous cycles caused by human activities • hypothesizing how alterations in the carbon cycle, as a result of the burning of fossil fuels, might influence other cycling phenomena • measuring the rates of precipitation and evaporation in the local area; and comparing this with precipitation and evaporation data of other areas of the province and/or the country • designing an experiment to compare carbon dioxide production by plants with that of animals • measuring the rates of water consumption and loss in plants and animals.	• analyzing how society affects the biogeochemical cycle of carbon, which in turn influences the greenhouse effect OR • discussing the influence of agricultural products or processes on the biogeochemical cycle of phosphorous and nitrogen; e.g., feedlot operations, composting, commercial fertilizer applications OR • evaluating the implications of the greenhouse effect on the hydrologic cycle and the water requirements of society and its agricultural systems OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. The balance of *energy* and *matter* exchange in the biosphere, as an open *system*, maintains its steady state *equilibrium*.	• air composition is influenced by the activities of organisms, by extending from Science 10, Unit 2, how energy and matter are exchanged between living systems and their environment, and by: • explaining how the equilibrium between gas exchanges in photosynthesis and cellular respiration influences atmospheric composition • describing how human activities can have a disrupting influence on the balance, in the biosphere, of photosynthetic and cellular respiratory activities; e.g., fossil fuel combustion, forest destruction.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the balance of energy and matter exchange in the biosphere and the influence of human activities on this equilibrium; and by predicting atmospheric equilibrium changes and designing models of closed systems in equilibrium, within the context of:
• predicting the effect of changes in carbon dioxide and oxygen concentration on the atmospheric equilibrium by a significant reduction of photosynthetic organisms through human activities • designing a model of a closed biological system in equilibrium with respect to carbon dioxide, water and oxygen exchange; e.g., space station, Biosphere II.	• discussing how the dynamic equilibrium of the atmosphere is influenced by human activity OR • examining the influence of changes to atmospheric ozone levels on society, agriculture, plants and animals OR • evaluating, from the past to the present, the evidence for changes in atmospheric composition, with respect to carbon dioxide and its significance to current biosphere equilibrium OR • evaluating the technology of a closed system; e.g., space station, Biosphere II OR • any other relevant context.

UNIT 2
ENERGY FLOWS AND CELLULAR MATTER

OVERVIEW

Science Themes: *Energy, Matter* and *Systems*

In Unit 2, students study photosynthesis as the process that obtains *energy* from the environment, and cellular respiration as the process that releases it again to do useful work in cellular *systems*. The associated cyclical fluxes of carbon and other forms of *matter* within the cellular *system*, between cells or between organisms, as *systems*, are outlined in general. It is not the intent of this unit that students learn the molecular details of the Calvin–Benson and Krebs cycles.

This unit builds on prior learning in Science 10, Unit 2: Energy and Matter in Living Systems. It provides an introduction to the exchange of *energy* and *matter* within *ecosystems* as described in Unit 3, and within organisms as described in Unit 4. It also prepares students for an examination of the role of *energy* in supporting the *systems* discussed in Biology 30, Unit 1: Systems Regulating Change in Human Organisms, and Unit 2: Reproduction and Development.

The two **major concepts** developed in this unit are:

- photosynthesis stores *energy* in organic compounds
- respiration releases potential *energy* from organic compounds.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities that demonstrate *energy* and *matter* exchange
- collecting and recording data on photosynthetic and respiratory activity
- connecting, synthesizing and integrating cellular biochemical phenomena.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate that *energy* and *matter* may flow at very different levels of organization
- appreciate that events at the molecular level support the functioning of living *systems*
- appreciate that biologists can pursue careers involving work at very different levels of biological organization
- appreciate the contributions that the other fields of natural science can make to the biological sciences
- value the maintenance of a healthy environment to prevent the malfunctioning of the basic processes of life.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Photosynthesis stores *energy* in organic compounds.	• light energy is stored in plants when photosynthesis uses light energy to synthesize carbohydrates, by extending from Science 10, Unit 2, the structure and function of membranes, and by: • explaining, in general terms, how pigments absorb light, transfer that energy as reducing power in nicotinamide adenine dinucleotide, reduced form (NADH), and to chemical potential in ATP by chemiosmosis, describing where those processes occur • explaining, in general terms, how the products of the light reactions, NADH and ATP, are used to reduce carbon in the Calvin–Benson cycle, describing where the process occurs in the cell.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding how light energy from the Sun is stored in organic compounds by photosynthesis; and by using chromatography technology to demonstrate, quantitatively, energy storage in plants; and by drawing analogies between biological energy storage and active solar storage, within the context of:
• using chromatography techniques to demonstrate that plant leaves contain a range of pigments • using experimental data to demonstrate, quantitatively, that plant leaves produce starch in the presence of light • drawing analogies between the storage of energy by photosynthesis and the storage of energy by active solar generating systems.	• analyzing the role of photosynthesis as the biological basis of agriculture and forestry OR • researching and analyzing the effects of herbicides on the biochemistry of photosynthesis OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Respiration releases potential *energy* from organic compounds.	• cellular respiration involves the release of stored energy from carbohydrates, as well as other organic molecules, by extending from Science 10, Unit 2, growth in living systems, and by: • explaining, in general terms, how carbohydrates are oxidized by glycolysis and Krebs cycle to produce reducing power in NADH and flavin adenine dinucleotide, reduced form (FADH), and chemical potential in ATP, describing where in the cell those processes occur; and understanding that specific detailed knowledge of the biochemistry of the reactions is not required • explaining, in general terms, how chemiosmosis converts the reducing power of NADH and FADH to the chemical potential of ATP, describing where in the cell the process occurs; and understanding that specific detailed knowledge of the biochemistry of the reactions is not required • explaining the role of oxygen in cellular respiration; e.g., aerobic, anaerobic • summarizing and explaining the role of ATP in metabolism; e.g., synthesis, movement, active transport • explaining how environmental pollutants, like cyanide or hydrogen sulfide, inhibit cellular respiration.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:

- designing and performing an experiment to demonstrate that a byproduct of respiration in both autotrophs and heterotrophs is heat
- demonstrating that respiration causes oxidation and an exchange of gases
- using experimental methods to demonstrate, quantitatively, the oxygen consumption of an animal
- drawing analogies between the role of ATP in a cell and money in an economic system
- investigating the action of metabolic toxins, such as hydrogen sulfide, on cellular respiration.

STS CONNECTIONS

Students should be able to demonstrate the interrelationships among science, technology and society, by:

- understanding that potential energy stored in organic compounds is released by cellular metabolic processes, the role of oxygen and ATP, and environmental influences on these processes; and by demonstrating, experimentally, heterotroph gas exchange; designing and performing metabolic experiments and investigating the action of metabolic toxins, within the context of:
  - discussing how specific compounds released into the environment, by society, may have precise metabolic effects on humans, plants and animals, and the desirability of regulating such releases

    OR
  - assessing the impact of research in cellular biochemistry on athletic training strategies

    OR
  - researching the technology of methane gas production from organic waste, and assessing the potential impact of this technology on the societies of less developed countries

    OR
  - any other relevant context.

UNIT 3
ENERGY AND MATTER EXCHANGE IN ECOSYSTEMS

OVERVIEW

Science Themes: *Diversity, Energy, Matter* and *Systems*

In Unit 3, students examine the biotic and abiotic factors that characterize *energy* and *matter* exchange in aquatic and terrestrial *ecosystems*. The unit closes by reviewing the process of organic evolution by natural selection. That process provides a model *system* to explain how the production of *diversity* allows for the selection of organisms better adapted to the roles they play in their *ecosystem*.

This unit builds on Biology 20, Unit 1: The Biosphere, and Unit 2: Energy Flows and Cellular Matter, providing a linkage between the biosphere and cellular phenomena by examining *energy* and *matter* flow in *ecosystems*. The unit provides the general context in which exchange between organisms and their environment are studied, and prepares students for analysis of populations and communities in Biology 30, Unit 4: Change in Populations and Communities.

The three **major concepts** developed in this unit are:

- the biosphere is composed of a *diversity* of biomes, each with distinctive biotic and abiotic factors
- *ecosystems* have characteristic structures determined by their *energy* and *matter* exchange
- populations are basic components of *ecosystem* structure.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning *ecosystem* research activities
- collecting and recording relevant data on the biotic and abiotic *ecosystem* components
- analyzing quantitative data on organism *diversity* and abiotic factors of *ecosystems*
- connecting, synthesizing and integrating the *energy* and *matter* exchange in *ecosystems* and predicting the future outcomes of those *ecosystems*.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the *diversity* of *ecosystems*
- value the knowledge that all organisms have an important role in maintaining the life of the planet
- develop an awareness of one's personal role in the preservation of the environment
- develop a sense of responsibility toward use of the environment
- appreciate the multidimensional nature of science, technology and society issues
- appreciate the contributions and limitations of scientific and technological knowledge to societal decision making
- value the necessity of being adaptable to *changes* in the environment
- appreciate the explanatory value of the modern synthesis of the Darwinian theory of evolution to all aspects of biology at all organizational levels, as well as appreciate the limitations of the theory
- respect and tolerate the personal and religious beliefs of others.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. The biosphere is composed of a *diversity* of biomes, each with distinctive biotic and abiotic factors.	• the biosphere is composed of biomes, each with many different ecosystems, characterized by physiographic, climatic, edaphic (soil) and biotic factors, by extending from Biology 20, Unit 1, energy and matter exchange in the biosphere, and by: • describing how energy and matter exchange contribute to the existence of the biosphere's major biomes; e.g., tundra, taiga, deciduous forest, rain forest • identifying ecosystem biotic and abiotic factors and explaining their influence in an aquatic and a terrestrial ecosystem in a local region; e.g., stream or lake, prairie, boreal forest, vacant lot, sports field.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the biosphere is composed of biomes and ecosystems, each distinctly characterized by their energy and matter exchange; and by performing field studies measuring, gathering and analyzing biotic and abiotic data; evaluating resource and technology dependability; hypothesizing the ecological roles of snow and ice; and predicting future outcomes of ecosystems, within the context of:
• performing a field study and measuring, quantitatively, appropriate abiotic factors, such as temperature, precipitation, snow depth, ice thickness, light intensity, pH, hardness and oxygen content in an aquatic and a terrestrial ecosystem; and presenting the data in a form, such as graphs, tables or charts, that describe, in general terms, the abiotic structure of the ecosystem chosen	• evaluating the impact that human activity has had, or could have, on the ecosystems chosen OR • analyzing the needs and interests of society that may influence the natural quality of water used for human consumption
• performing a field study and gathering and analyzing both quantitative and qualitative data on the diversity of plant, animal and decomposer species in the ecosystem chosen; and presenting the data in a form that describe, in general terms, the biotic structure of the ecosystem chosen	OR • discussing the impact of "slash and burn" or "clear-cutting" practices of societies on the stability and energy flow of the ecosystem involved
• hypothesizing the ecological role of biotic and abiotic factors; e.g., albedo effect, competition	OR • any other relevant context.
• evaluating the dependability of resources, including technologies, used for measurement, assessment or analysis; and identifying the degree of bias in a field study.	

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. *Ecosystems* have characteristic structures determined by their *energy* and *matter* exchange.	• the structure of ecosystems can be described, by extending from Biology 20, Unit 2, the relationship between photosynthesis and respiration, and by: • explaining, quantitatively, the structure of ecosystem trophic levels, using models, such as food chains and webs • explaining, quantitatively, the energy and matter exchange in ecosystems, using models, such as pyramids.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding how the nature of energy and matter exchange determines ecosystem structure and representing this information in models; and by collecting and analyzing energy and matter exchange information, and building models from this information, within the context of:
• collecting information and building a model depicting the food web of a chosen ecosystem • evaluating, quantitatively, the energy and matter exchange in a chosen ecosystem, using a pyramid of mass or numbers • analyzing data on the diversity of plants, animals and decomposers that make up the biotic component of a specific endangered ecosystem; and predicting the future outcome of that ecosystem.	• discussing the impact of the draining of wetlands for reclamation and society's responsibility to use natural resources judiciously OR • analyzing the interrelationship between the introduction of heavy metals into the environment and matter exchange in natural food chains/webs, and the impact of this on quality of life OR • researching the effect single-crop monoculture has on food webs and species diversity in the ecosystem, and the influence of the needs and interests of society on this practice OR • assessing the environmental consequences of the introduction of new species to isolated, established ecosystems and the responsibility of society, through science and technology, to protect the environment OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Populations are basic components of *ecosystem* structure.	• there is a great deal of variation within populations, by:
	• describing, in general terms, the nature of variation within populations; e.g., inherited versus acquired, continuous versus discontinuous
	• explaining how populations are adapted to their environment; e.g., drug resistance, cold tolerance
	• explaining, in general terms, how a great range of variation exists within individual populations; e.g., blood groups, enzymes
	• summarizing and describing lines of evidence to support the evolution of modern species from ancestral forms; e.g., hominids, horses
	• describing natural selection and explaining its action on future populations leading to evolutionary change.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that populations are the basic component of ecosystem structure, including range of variation, environmental adaptation and evidence supporting evolutionary change; and by designing and performing experiments to measure variation, hypothesizing adaptive significance of variations; and analyzing morphology changes over time, within the context of:
• designing and performing an experiment to measure inherited variation in a plant or animal population • formulating hypotheses about the adaptive significance of the variations in a range of homologous structures in extant (still existing) and extinct organisms • gathering and analyzing data, actual or simulated, on plants or animals to demonstrate how morphology evolves over time; e.g., corn, Darwin's finches, pepper moths.	• discussing the nature of science as a way of knowing, compared with other ways of knowing; e.g., origin of life OR • describing how paleontology and the role of evidence in the accumulation of knowledge has provided invaluable data for theories explaining observable variations in organisms over time OR • comparing society's interpretation of variations within populations and change over time with those of Darwin's era; and realizing the inability of science to provide complete answers OR • researching the contributions of Charles Lyell, Thomas Malthus and Alfred Wallace, among others, to Darwin's understanding of species change, the role of evidence in the accumulation of knowledge, and the eventual formation of Darwin's concept of natural selection and origin of species OR • any other relevant context.

UNIT 4
ENERGY AND MATTER EXCHANGE BY THE HUMAN ORGANISM

OVERVIEW

Science Themes: *Energy, Equilibrium, Matter* and *Systems*

In Unit 4, students use the human organism as a model *system* to examine the processes that mediate the interactions between organisms and their environment. These processes maintain metabolic *equilibrium*. *Energy* and *matter* are exchanged between humans and their environment during the processes of respiration, digestion and excretion. These processes are carried out with the aid of a circulatory *system* that is also part of a defence *system*. Regulation of the interactions between pathogens and the human organism help maintain metabolic *equilibrium*.

This unit builds on learning from Science 10, Unit 1, Energy from the Sun, and Unit 2: Energy and Matter in Living Systems, and the other three units in this course. It provides a structural and functional context in which control *systems* can be studied in Biology 30, Unit 1: Systems Regulating Change in Human Organisms.

The three **major concepts** developed in this unit are:

- the human organism's digestive and respiratory *systems* exchange *energy* and *matter* with the environment
- the human organism's excretory *system* exchanges *energy* and *matter* with the environment
- the human organism's circulatory *system* transports *energy* and *matter* to maintain *equilibrium* among the body *systems* as well as between the organism and its external environment.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities to investigate the role of selected human organ *systems* in *energy* and *matter* exchange
- collecting and recording relevant biochemical data from a variety of physiological processes
- analyzing data and information from a variety of biochemical and physiological experiments
- connecting, synthesizing and integrating by drawing analogies among villi, alveoli, nephrons and capillaries; and by integrating information from models, simulations and research to demonstrate how *equilibrium* is maintained with respect to *energy* and *matter* exchange.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- appreciate the importance of the relationship between the human organism and its environment in maintaining homeostasis
- appreciate the hierarchical organization of the human organism
- foster a curiosity about the structure and function of the human organism's *systems*, and their role in maintaining *equilibrium* with the environment
- appreciate how the digestive, respiratory, excretory, transport and defence *systems* are closely linked to cellular respiration
- develop a commitment to learning about the function of organs and *systems* in the human organism and the importance of maintaining personal health
- appreciate the complex and precise nature of the immune *system* and its sensitivity to factors like stress and infection
- appreciate the interactive nature of science and technology in developing products and processes that promote or inhibit the functioning of the human organism's *systems*
- appreciate the ethical dilemmas that may arise as a result of science and technology being used to influence the functioning of the human organism.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. The human organism's digestive and respiratory *systems* exchange *energy* and *matter* with the environment.	• human organisms, like other organisms, must exchange energy and matter by extending from Science 10, Unit 1, systems and Unit 2, concepts of surface area to volume ratio and membrane transport, and by: • describing the intake of matter from the environment, its chemical and physical processing through the digestive system into the blood stream and the return of the remaining material to the environment • explaining how gases and heat are exchanged between the human organism and its environment.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that human digestive and respiratory systems exchange energy and matter with the environment; and by observing system structure and function; designing and performing experiments identifying matter exchanged, quantifying energy exchanged, investigating enzyme function and gas exchange mechanisms, within the context of:
• observing the principal features of the digestive and respiratory systems of a mammal, using models, computer simulations or dissected organisms; and identifying the structures from drawings of those systems; e.g., villi, alveoli	• discussing and evaluating the role of food additives to solve the problems of food spoilage; e.g., antioxidants, irradiation technology OR
• performing experiments to detect the presence, in food, of organic molecules, such as carbohydrates, lipids and proteins, using qualitative chemical tests	• explaining the biological basis of nutritional deficiencies; and evaluating how diet can adversely affect the equilibrium of other body systems; e.g., anorexia nervosa OR
• designing and performing a calorimetry experiment to determine, quantitatively, the potential energy of carbohydrates and fats in foods	• assessing the physiological effect of such legal drugs as alcohol and nicotine on digestive and respiratory functions OR
• performing an experiment to demonstrate the action of digestive enzymes from plant or animal tissue; e.g., potato, liver	
• designing and performing experiments to investigate the influence of enzyme concentration, temperature and pH on the activity of enzymes; e.g., pepsin, pancreatin	• evaluating the ethical implications of organ transplants in terms of the needs, interests and financial support of society on scientific and technological research in this field; e.g., societal and scientific definitions of death OR
• designing and performing experiments to investigate the mechanics of breathing; e.g., lung volume, breathing rate.	• any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The human organism's excretory *system* exchanges *energy* and *matter* with the environment.	• human organisms, like other organisms, must maintain an equilibrium with respect to their internal environment, by: • explaining the role of the kidney in excreting metabolic wastes from the body and expelling them into the environment • explaining how the excretory system maintains internal equilibrium with respect to water, pH and ions.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the role of the human excretory system in excretion of wastes and balance of water and ions; and by performing simulated urine composition experiments, analyzing data to summarize the role of the kidney; and researching the human excretory function for the purpose of designing models of kidney function, within the context of:
• performing an experiment to investigate simulated urine composition, analyzing the data and summarizing the role of the kidney in homeostatic regulation of water, pH and ionic substances	• identifying specific pathologies of the digestive, excretory, respiratory and circulatory systems, and the technology used to ease or cure the problems OR
• researching the human excretory system and designing a flow chart model to describe how the human organism maintains homeostasis with respect to water and ions in a situation where either the water intake was high; e.g., tea, coffee, soda pop, or where the sodium ion intake was excessive; e.g., anchovy pizza, cheese	• examining the relationships that exist among lifestyles, hypertension and kidney function OR • any other relevant context.
• making analogies between kidney function and renal and peritoneal dialysis.	

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. The human organism's circulatory *system* transports *energy* and *matter* to maintain *equilibrium* among the body *systems* as well as between the organism and its external environment.	• human organisms must maintain an internal equilibrium with respect to organs and organ systems, as well as equilibrium with their external environment, by: • explaining the role of the circulatory system in aiding the digestive, excretory and respiratory systems' exchange of energy and matter with the environment • explaining the role of the body surface in maintenance of organism equilibrium; e.g., temperature regulation, protection from pathogens • describing the main components of blood and their role in transport, and their role in resisting the influence of pathogens; e.g., erythrocytes, leucocytes, platelets, plasma • listing main cellular and noncellular components of the human immune system and describing their role; e.g., macrophage, helper T cell, B cell, killer T cell, suppressor T cell, memory T cell.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the human circulatory system maintains an equilibrium among systems and with the external environment, exchanging thermal energy, and providing pathogen protection through the immune system and its cellular components; and by observing circulatory and excretory system morphology and capillary flow, measuring system pressure; and researching and designing immune system models, within the context of:
• observing the principal features of the circulatory and excretory systems of a mammal, using models, computer simulations or dissected organisms; and identifying the structures from drawings of those systems • summarizing, from models, computer simulations or a dissected organ, the structures and direction of blood flow through a mammalian heart • using a microscope to observe blood flow in the capillaries of a living organism; e.g., goldfish • performing experiments that measure venous pressure in humans • measuring and interpreting their own blood pressure; and investigating the role of exercise in influencing blood pressure • using a microscope to examine prepared slides of human blood to observe the morphology and relative abundance of the cellular components of the blood • researching and designing a simulation or model of the functioning of the main components of the human immune system.	• researching experimental evidence on disruptions to human circulatory equilibrium caused by severe burns OR • analyzing how technological advances assist the circulatory system in the delivery of prescription drugs to their sites of action OR • describing how biotechnology can assist in the maintenance of internal equilibrium with respect to pathogens OR • evaluating the needs, interest and financial support society has on preventing the spread of disease-causing organisms, like *Staphylococcus*, smallpox virus and the human immunodeficiency virus (HIV) OR • any other relevant context.

BIOLOGY 30

UNIT 1
SYSTEMS REGULATING CHANGE IN HUMAN ORGANISMS

OVERVIEW

Science Themes: *Equilibrium* and *Systems*

Unit 1 uses the human organism as a model *system* to study that *equilibrium* between an organism's internal environment and its external environment can be maintained by metabolic or behavioural means. Endocrine glands and other *systems* maintain physiological *equilibrium* mediated by hormones. A study of the interaction between the neural and endocrine *systems* leads to an examination of the functioning of the central and peripheral nervous *systems* and their ability to sense the environment and respond to it. That ability is important in maintaining organism *equilibrium.*

This unit builds on Science 10, Unit 1: Energy from the Sun, Unit 2: Energy and Matter in Living Systems; and Biology 20, Unit 4: Energy and Matter Exchange by the Human Organism, by examining the biological processes that mediate the interactions between organisms and their environment to maintain a desirable *equilibrium.* This unit leads to further study of control *systems* in Unit 2, and to post-secondary studies.

The two **major concepts** developed in this unit are:

- the human organism regulates physiological processes, using electrochemical control *systems*
- the human organism maintains homeostasis through the use of complex chemical control *systems.*

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities demonstrating the human response to a variety of environmental stimuli to maintain its *equilibrium*
- collecting and recording neural and hormonal data from observations and published research
- analyzing physiological data
- connecting, synthesizing and integrating data from activities that predict the role of control *systems* in the maintenance of organism *equilibrium*
- evaluating the processes or outcomes of neural and hormonal research and identifying their limitations.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- foster curiosity about the structure and function of the human organism's endocrine and neural control *systems* and their role in maintaining homeostasis
- appreciate the complexity and precise nature of the neural and endocrine *systems* and the importance of their integrating functions in maintaining *equilibrium*
- develop a commitment to learning about the functioning of the neural and endocrine *systems* and the importance of maintaining personal health
- appreciate the interactive nature of science and technology in developing products and processes that promote or inhibit the functioning of the human organism's *systems*
- appreciate the ethical dilemmas that may arise as a result of science and technology being used to influence the functioning of the human organism.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. The human organism regulates physiological processes, using electrochemical control *systems*.	• the human organism, like other organisms, maintains control over its internal environment with neural systems, by extending from Science 10, Unit 1, energy systems, Science 10, Unit 2, cell processes and Biology 20, Unit 4, the biological systems that maintain the organism's equilibrium with the environment, and by: • describing the structure and function of a neuron and myelin sheath, explaining the formation and transmission of an action potential and the transmission of a signal across a synapse or neuromuscular junction and the main chemicals and transmitters involved; i.e., norepinephrine, acetylcholine and the enzyme that breaks them down • describing the composition and function of a simple reflex arc and the organization of neurons into nerves • identifying the principal structures of the central and peripheral nervous systems and explaining their functions in regulating the voluntary (somatic) and involuntary (autonomic) systems of the human organism; e.g., cerebral hemispheres, cerebellum, pons, medulla, hypothalamus, pituitary, spinal cord, sympathetic and parasympathetic nervous systems • explaining how human organisms sense their environment and their spatial orientation in it; e.g., auditory, visual, skin receptors, olfactory, proprioceptors.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding how human physiological processes are regulated by electrochemical control systems, describing the structure and function of neurons, the central and peripheral nervous systems, and sensory input transducers; and/or by observing the principal features of a neuron, mammalian brain and eye; and designing and performing experiments to investigate reflex arcs and sensory input, within the context of:
• observing neurons and neuromuscular junctions on prepared microscope slides	• analyzing experimental evidence for the influence of anesthetics, drugs and chemicals, natural and synthetic, on the functioning of the nervous system, and their relationship to addiction theories
• designing and performing experiments to investigate the physiology of reflex arcs	OR
• observing the principal features of the mammalian brain, using models, computer simulations or dissected mammalian brains; and identifying the major visible structures from drawings or models of that organ	• discussing the biological basis of neurological diseases, like Alzheimer's or Parkinson's
	OR
• observing the principal features of the mammalian eye and ear, using models, computer simulations or dissected mammalian eyes; and identifying the major visible structures from drawings or models of those organs	• discussing how advances in science and technology have increased access to the world beyond normal sensory limits
	OR
• designing and performing experiments to investigate heat, cold, pressure and touch receptors, and the ability to sense environment	• evaluating the application of biological knowledge in developing offensive and defensive military capabilities
	OR
• performing experiments to measure the ability to discriminate objects visually and to hear a range of sounds.	• discussing and evaluating the effect of science and technology on longevity and quality of life
	OR
	• evaluating the impact of photoperiod, light wavelength and duration on the human organism
	OR
	• any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The human organism maintains homeostasis through the use of complex chemical control *systems*.	• endocrine systems coordinate other organ systems through feedback to maintain internal homeostasis as well as the organism's equilibrium with the environment, by extending from Biology 20, Unit 4, the maintenance of metabolic equilibrium, and by: • identifying the principal endocrine glands of the human organism; e.g., the hypothalamus/pituitary complex, thyroid and adrenal glands, pancreas islet cells • describing the hormones of the principal endocrine glands; i.e., TSH/thyroxine, ACTH/cortisol glucagon/ insulin, HGH, ADH, epinephrine, norepinephrine, aldosterone • explaining the metabolic roles hormones play in homeostasis; i.e., thyroxine to metabolism, insulin to blood sugar regulation, HGH to growth, ADH to water regulation • explaining how the endocrine system allows human organisms to sense their internal environment and respond appropriately; e.g., sugar metabolism • comparing the endocrine and neural control systems and explaining how they act together; e.g., stress and the adrenal gland • describing, using an example, the physiological consequences of hormone imbalances.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*

STS Connections

- understanding that homeostasis of organs and organ systems is regulated, in part, by chemical control systems; and describing the main components and hormones of the human endocrine system, their metabolic role, and their interaction with the nervous system; and by inferring and interpreting from data, the role of insulin, ADH and aldosterone; and evaluating the components of the "general adaptation syndrome", within the context of:
    - evaluating the use of biotechnology to solve practical hormone problems; e.g., hormone synthesis for diabetes, dwarfism, milk yields in cows

      OR

    - comparing the function of technological control systems with electrochemical control systems in organisms; e.g., computer control systems for car emissions

      OR

    - assessing the impact on athletics of research into biochemical control systems

      OR

    - explaining the relationship among ultraviolet light, ozone depletion and pigment deposition within skin cells

      OR

    - discussing the use of hormone therapy in the treatment of humans; e.g., growth hormone and aging, steroids and sports

      OR

    - any other relevant context.

Skills

- inferring the role of insulin in the regulation of blood sugar, by performing an experiment to investigate the presence of reducing sugars in simulated urine; and comparing the results with urinalysis data; and/or investigating the role of insulin in the regulation of blood sugar, using a computer simulation
- inferring the role of ADH and aldosterone in the maintenance of homeostasis of water and ions, by the analysis and interpretation of data on blood and urine composition
- formulating hypotheses from published data on an environmental factor that can be detected and responded to by the human organism; e.g., ultraviolet light and pigment deposition, diet and thyroid function
- researching, identifying and summarizing the main hormonal and nervous components in stress management; i.e., "general adaptation syndrome."

UNIT 2
REPRODUCTION AND DEVELOPMENT

OVERVIEW

Science Themes: *Change* and *Systems*

Unit 2 studies the concept that species must reproduce themselves to ensure their survival. The processes associated with reproduction and development are reviewed here to illustrate their physiological regulation by using the human organism as a model *system*. *Change* can be induced in the reproductive and other *systems* of organisms by hormones from a variety of glands. *Change* also occurs as gametes are produced, fuse to form zygotes and undergo development. The regulation of these processes by hormonal *systems* is examined. The *systems* associated with parturition and lactation are regulated hormonally.

This unit builds upon Biology 20, Unit 4: Energy and Matter Exchange by the Human Organism; on the learning of biological control *systems* from Unit 1; and leads to a more detailed study of gametogenesis and genetics in Unit 3, and to post-secondary studies.

The three **major concepts** developed in this unit are:

- humans and other organisms have complex reproductive *systems* that ensure the survival of the species
- reproductive success of organisms is regulated by chemical control *systems*
- cell differentiation and development in the human organism are regulated by a combination of genetic, endocrine and environmental influences.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording reproductive data
- analyzing research information on hormonal data and physiological events
- connecting, synthesizing and integrating, from research information, the influence of internal and environmental factors on life span development
- evaluating the processes or outcomes of knowledge about research in human reproduction and the consequences or limitations of this research.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the ways in which science advances technology and technology advances science
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate that there are biological and societal aspects to the study of reproduction
- appreciate the association among health, reproduction and development
- appreciate the ethical dilemmas that may arise from the application of scientific research and/or technological developments to reproductive and developmental processes
- appreciate the multidimensional nature of science, technology and society issues
- respect and tolerate the personal and religious beliefs of others.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Humans and other organisms have complex reproductive *systems* that ensure the survival of the species.	• human organisms have evolved a specialized series of ducts and tubes to facilitate the union of an egg and sperm, by: • describing hormonal and chromosomal factors and explaining the physiological events resulting in the formation of the primary (gonads) and secondary (associated structures) reproductive organs in the female and male fetus • identifying the structures and describing their functions in female (e.g., ovaries, fallopian tubes, uterus, cervix, vagina) and male (e.g., testes, epididymus, vas deferens, seminal vessicles, prostate gland, penis) reproductive systems • explaining how sexually transmitted diseases can interfere with the passage of eggs and sperm; e.g., chlamydia, gonorrhea.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the development of human reproductive organs; and describing the anatomical structures that facilitate gamete union and species survival; and explaining the role of sexually transmitted diseases in this process; and by observing the principal features of human reproductive systems; and identifying eggs, sperm and supporting structures from slides, within the context of:
• observing the principal features of the human reproductive system, using models or computer simulations; and identifying the major structures from drawings of that organ system • distinguishing eggs and sperm from their supporting structures, using prepared slides of ovaries and testes; e.g., interstitial cells, follicle, corpus luteum, seminiferous tubules.	• evaluating the implications of reproductive technology for human biology OR • discussing society's expectations of the scientific community with respect to reproductive technology OR • identifying the types of physiological and physical damage caused by exposure to sexually transmitted disease organisms in females and males OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Reproductive success of organisms is regulated by chemical control *systems.*	• the development of sexual anatomy and sexual functioning is influenced by hormones, by: • describing the role of hormones in the regulation of primary and secondary sex characteristics in females and males • identifying the principal reproductive hormones in the female and explaining their interactions in the maintenance and functioning of the female reproductive system; e.g., estrogen, progesterone, LH, FSH, prolactin, oxytocin • identifying the principal reproductive hormones in the male and explaining their interactions in the maintenance and functioning of the male reproductive system; e.g., testosterone, luteinizing hormone (LH), follicle stimulating hormone (FSH) • comparing the cyclical patterns of reproduction in humans with that of nonprimate mammals.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that human reproductive success, development of secondary sexual characteristics, formation of gametes and reproductive system maintenance are regulated by hormones; and by analyzing and inferring from data and physiological events the roles of sex hormones, within the context of:
• analyzing blood hormone data and physiological events of a single menstrual cycle, and inferring the roles of the female sex hormones • analyzing blood hormone data and physiological events, and inferring the roles of the male sex hormones.	• researching and assessing the effects of the medical use of reproductive hormones on humans OR • explaining how reproductive hormone homeostasis is disrupted by the natural aging process OR • researching and assessing the value of producing and using reproductive hormones in domestic animals, such as cattle and horses OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Cell differentiation and development in the human organism are regulated by a combination of genetic, endocrine and environmental influences.	• events following conception are governed by a combination of genetic, endocrine and environmental influences, by extending from Biology 20, Unit 4, the human organism as a system, and by: • tracing the processes of fertilization, implantation, extraembryonic membrane formation (e.g., amnion, chorion, yolk sac, placenta), embryo development, parturition and lactation, and the control mechanisms of those events; e.g., progesterone, LH, chorionic gonadotropin, oxytocin, prolactin • describing fetal development from implantation to full term in the context of the main physiological events that occur in the development of organ systems during each major stage (trimester) and the influence of environmental factors on the development of these systems; e.g., alcohol, drugs, pathogens • describing the physiological or mechanical basis of different reproductive technology methods; e.g., conception control, in vitro fertilization, infertility reversal.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding how development from conception is regulated by genetics, hormones and environment; and describing these developmental events and the technologies that influence them; and by observing slides, models or computer simulations of nonhuman embryo development, investigating environmental influences on the embryo/fetus and assessing safety reproductive technology, within the context of:
• observing the stages of embryo development, using preserved material, such as chicken embryos, prepared slides, models or computer simulations; and extrapolating these events to the development of a human fetus • investigating the effects of environmental factors, such as alcohol and nonprescription drugs, on the development of the human fetus • evaluating, from published data, the effectiveness and safety of the various reproductive technology methods • interpreting hormonal data from published investigations; e.g., pregnancy testing.	• analyzing the use of technology to solve problems of incompatibility between fetus and mother, and possible solutions to such problems OR • assessing the societal impact of reproductive imaging technologies; e.g., ultrasound, magnetic resonance image ray (MRI), X-rays OR • discussing how knowledge of embryo/fetus development has influenced society's values on human life OR • discussing the societal impact of chemicals and drugs on fetal development; e.g., alcohol and cocaine OR • assessing the effects of hormonal conception control technology on population demographics in developed and underdeveloped countries OR • any other relevant context.

UNIT 3
CELLS, CHROMOSOMES AND DNA

OVERVIEW

Science Themes: *Change* and *Diversity*

In Unit 3, students examine the cell and molecular biology of mitosis as well as its limitations in providing *diversity*. The significance of meiosis as a way by which organisms can introduce *diversity* into their descendants is introduced. The timing and location of meiosis in the reproductive biology of the human organism is discussed. The studies of classical genetics are reviewed to show how phenotypes may *change* through generations. Classical genetics is extended to a molecular level where the role of DNA in producing RNA, then proteins, is reviewed. The principles of introducing *change* into the sequence of bases in DNA is examined.

This unit builds on Science 10, Unit 2: Energy and Matter in Living Systems, where simple cell division was introduced and Biology 30, Unit 2: Reproduction and Development, where spermatogenesis and oogenesis were introduced. This unit leads to a study of population genetics in Unit 4, and to post-secondary study.

The three **major concepts** developed in this unit are:

- cells divide to increase in number but must reduce their chromosome number before combining at fertilization
- genetic characters are handed down by simple rules
- classical genetics can be explained at a molecular level.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities that demonstrate genetic inheritance patterns and environments
- collecting and recording empirical data on single gene inheritance, cell division and information from computer simulations and models
- analyzing published and collected genetic information for trends, patterns and relationships
- connecting, synthesizing and integrating various types of genetic and cellular information.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- be open-minded toward new evidence, and be aware of the *changes* it may promote
- appreciate that extension of learning requires new knowledge, skills, attitudes and risk taking
- value the development of information, science and technology, while continuing to cultivate human values
- appreciate the usefulness of computational competence and the problem-solving skills required by classical genetics
- develop a positive attitude toward mathematical and scientific process skills
- appreciate the ethical dilemmas that may arise from the application of scientific research and/or technological developments as they relate to the field of genetics
- appreciate, and be critical about, current research and theories concerning genetic information.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Cells divide to increase in number but must reduce their chromosome number before combining at fertilization.	• chromosomes are duplicated before cells divide; that daughter cells get one complete set of chromosomes; that chromosome number must be reduced before fertilization; and that variations in the combination of genes on a chromosome can occur during that reduction, by recalling from Science 10, Unit 2, that growth may involve increasing cell number, and by: • explaining, in general, the events of the cell cycle, including cytokinesis, and chromosomal behaviour in mitosis and meiosis • describing the processes of spermatogenesis and oogenesis and the necessity for chromosomal number reduction in meiosis • describing the processes of nondisjunction and crossing over; and evaluating their significance on organism development • comparing the processes of mitosis and meiosis • comparing the formation of fraternal and identical offspring in a single birthing event • describing the diversity of reproductive strategies by comparing the alternation of generations in a range of plants and animals; i.e., pine, bee, mammal.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:

- identifying the stages of the cell cycle; and calculating the duration of each stage from observations of prepared slides of onion root tip cells
- preparing microscope slides to demonstrate some stages of mitosis and meiosis
- performing a simulation to demonstrate the behaviour of chromosomes during meiosis
- researching a range of reproductive strategies in seed plants and animals; and presenting this information in the form of charts, tables or diagrams; e.g., budding, spore production, binary fission
- preparing and interpreting models of human karyotypes.

STS CONNECTIONS

Students should be able to demonstrate the interrelationships among science, technology and society, by:

- understanding that mitosis results in cell division and genetic continuity, and meiosis results in gamete formation and genetic variation; and by observing actively dividing cells, performing meiosis simulations and researching reproductive strategies in plants and animals, within the context of:
  - discussing the role of mitosis and biotechnology in regenerating damaged or missing parts of organisms

    OR
  - evaluating how a knowledge of cell division might be applied to the limitation of cancerous growth in plants or animals

    OR
  - discussing the types and sources of various teratogenic compounds found in the environment and the responsibility of society, through science and technology, to ensure quality of life for future generations

    OR
  - evaluating the impact of research in plant and animal reproduction on our understanding of mitosis and meiosis in humans

    OR
  - any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Genetic characters are handed down by simple rules.	• chromosomes consist of a sequence of genes and their alleles, and that during meiosis and fertilization these genes become combined in new sequences, by extending from Biology 30, Unit 2, fertilization and development in the human organism, and by: • describing the evidence for the segregation of genes and the independent assortment of genes on different chromosomes, as investigated by Mendel • explaining the influence of crossing over on the assortment of genes on the same chromosome; e.g., gene linkage • explaining the significance of sex chromosomes compared to autosomes, as investigated by Morgan.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*

SKILLS

- performing experiments to investigate the relationships between chance and genetic inheritance
- performing simulations to investigate monohybrid and dihybrid genetic crosses, by using Punnett squares
- designing a procedure and collecting data in peer groups or families to demonstrate the presence of single and multiple alleles in human inheritance
- drawing and interpreting pedigree charts from data on human single allele and multiple allele inheritance patterns; e.g., blood types
- predicting, quantitatively, the probability of inheritance from monohybrid, dihybrid and sex-linked inheritance data
- designing and performing an experiment to demonstrate the inheritance pattern of a trait controlled by a single pair of genes.

STS CONNECTIONS

- understanding how genetic characters are handed down by simple rules; and describing evidence for gene segregation and explaining the significance of crossing over and sex chromosomes; and by drawing and interpreting pedigree charts; and performing simulations or experiments to predict inheritance patterns, within the context of:
  - evaluating, from a variety of perspectives, the needs and interests of society and the role of genetic counselling in the identification and treatment of potentially disabling genetic disorders; e.g., phenylketonuria

    OR

  - discussing the role of gene banks used to preserve endangered species and genotypes, particularly of plants and animals used in agriculture; and the responsibility of society to protect the environment for future generations

    OR

  - discussing biotechnology and gene replacement therapy in the treatment of human genetic disorders

    OR

  - any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Classical genetics can be explained at a molecular level.	• genetic information in chromosomes is translated into protein structure; that the information may be manipulated; and that the manipulated information may be used to transform cells, by: • summarizing the historical events that led to the discovery of the structure of the DNA molecule, as described by Watson and Crick • describing, in general, how genetic information is contained in the sequence of bases in DNA molecules in chromosomes; how the DNA molecules replicate themselves; how the information is transcribed into sequences of bases in RNA molecules and is finally translated into sequences of amino acids in proteins • explaining, in general, how restriction enzymes and ligases may cut DNA molecules into smaller fragments and reassemble them with new sequences of bases • explaining, in general, how cells may be transformed by inserting new DNA sequences into their genomes • explaining how a random change (mutation) in the sequence of bases provides a source of genetic variability • explaining how information in nucleic acids contained in the nucleus, mitochondria and chloroplasts gives evidence for the relationships among organisms of different species.

SKILLS	STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:

- predicting the general arrangement of genes in a chromosome, from analysis of data on crossing over between genes in a single pair of chromosomes
- designing and constructing models of DNA to demonstrate the general structure and base arrangement
- performing simulations to demonstrate the replication of DNA and the transcription and translation of its information
- designing and performing an experiment to demonstrate how an environmental factor can cause a change in the expression of genetic information of an organism
- performing simulations to demonstrate the use of restriction enzymes and ligases in creating new DNA sequences; e.g., electrophoresis
- analyzing and inferring, from published data, the relationship between human activities and changes in genetic information, that lead to inheritable mutations and cancer.

Students should be able to demonstrate the interrelationships among science, technology and society, by:

- understanding how DNA structure and function can explain classical genetics; and explaining DNA manipulation, mutations and DNA evidence for organism relationships; and by predicting gene sequences; designing and constructing DNA models; performing experiments to demonstrate DNA expression; and analyzing and inferring the relationship between human activities and mutations, within the context of:
  - evaluating the use of genetically engineered organisms in agriculture and forestry; and bioremediation in the natural environment

    OR

  - debating the societal and scientific definitions of life and the living condition

    OR

  - discussing the Human Genome Project in terms of the needs, interests and financial support of society

    OR

  - discussing the implications to society of corporations being able to patent new life forms produced by biotechnology

    OR

  - assessing the impact of DNA mapping technology on the study of genetic relationships and variations in population ecology

    OR

  - any other relevant context.

UNIT 4
CHANGE IN POPULATIONS AND COMMUNITIES

OVERVIEW

Science Themes: *Change, Equilibrium* and *Systems*

Unit 4 introduces students to genetic principles that may be used to analyze population *systems*, and an example is drawn with the Hardy–Weinberg *equilibrium*. The reasons for populations not being in *equilibrium* are reviewed. Population growth and growth strategies are discussed. The interactions of organisms in human or natural *systems*, and the consequences of such interactions for populations and communities in those *systems*, are investigated. Populations of different organisms exist in communities that may *change* over time as a result of natural or artificial events. A review of such successional events completes the unit.

This unit builds on the learning from Biology 20, Unit 3: Energy and Matter Exchange in Ecosystems. This unit, the course and the program, may lead to careers or post-secondary study in the biological sciences.

The three **major concepts** developed in this unit are:

- communities are made up of populations that consist of pools of genes from the individuals of a species
- individuals of populations interact with each other and members of other populations
- population *change* over time can be expressed in quantitative terms.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities to demonstrate population growth and *change* over time
- collecting and recording empirical data on population and community *change*
- analyzing published data, collected data and information from computer simulations and models
- connecting, synthesizing and integrating *ecosystem* information from a variety of sources to interpret and explain community *change* and *equilibrium*.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- be open-minded toward new evidence and be aware of the *changes* it may promote
- appreciate the usefulness of computational competence and problem-solving skills required by population genetics
- develop a positive attitude toward mathematical and scientific process skills
- appreciate the *diversity* in populations and communities
- appreciate that *change* occurs in populations and communities over very long and short time scales

- value the knowledge that all organisms have an important role in maintaining the life of the planet
- develop optimism about the human ability to learn to function within the limits of sustainable development
- develop an attitude of participation in planning and shaping the future
- appreciate the contributions and limitations of scientific and technological knowledge to societal decision making.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Communities are made up of populations that consist of pools of genes from the individuals of a species.	• populations can be defined in terms of their gene pools, by extending from Biology 20, Unit 3, the nature of variation and adaptation in populations, and by: • describing the Hardy–Weinberg principle and explaining its importance to population gene pool stability and the significance of nonequilibrium values; e.g., evolution of a population • describing the conditions that cause the gene pool diversity to change; e.g., random genetic drift, gene migration, differential reproduction • applying, quantitatively, the Hardy–Weinberg principle to observed and published data • describing the molecular basis and significance of gene pool change over time; i.e., mutations.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that communities consist of population-specific gene pools; and explaining the significance of the Hardy–Weinberg principle and the molecular basis of gene pool change over time; and by applying and interpreting the Hardy–Weinberg principle, and performing experiments to demonstrate population growth, within the context of:
• calculating and interpreting problem-solving exercises involving the Hardy–Weinberg principle expressed as $p^2 + 2pq + q^2 = 1$ • performing experiments and/or computer simulations to demonstrate population growth and gene pool change.	• discussing the implications of the introduction of exotic species into an ecosystem where natural predators do not exist, and methods to deal with situations arising therefrom OR • debating the role of ecological reserves in preserving our natural heritage OR • assessing the role and importance of models in science to explain observable phenomena; e.g., the Hardy–Weinberg principle OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Individuals of populations interact with each other and members of other populations.	• interactions occur among members of the same population of a species as well as among members of populations of different species, by: • describing the basis of symbiotic relationships, i.e., commensalism, mutualism, parasitism, and interspecific and intraspecific competition and their influences on population changes • describing the relationships between predator and prey species and their influence on population changes; and explaining the role of defence mechanisms in predation; e.g., mimicry, protective colouration • explaining how mixtures of populations that define communities may change over time or remain as a climax community; e.g., primary succession, secondary succession.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that individuals interact with each other and other populations, and that communities and their populations change over time; and by summarizing and evaluating relationships; and by performing predatory–prey simulations; and designing and performing experiments demonstrating biotic interactions, within the context of:
• summarizing and evaluating the symbiotic relationship between a parasite and its host • designing and performing an experiment to demonstrate interspecific and/or intraspecific competition • performing simulations to investigate the relationships between predators and their prey • designing and performing an experiment to demonstrate succession in a micro-environment, and recording its pattern of succession over time.	• discussing the implications of the predator–prey relationship for wildlife management in national and provincial parks OR • investigating the long-term implications of ecosystem fire control and prevention on population and ecosystem stability and diversity OR • analyzing the relationship between parasites and human developmental potential in less developed countries OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Population *change* over time can be expressed in quantitative terms.	• populations grow in characteristic ways, and that the changes in population growth can be quantified, by extending from Biology 20, Unit 3, variations within populations, and by: • describing and explaining, quantitatively, factors that influence population growth; i.e., mortality, natality, immigration, emigration • describing the growth of populations in terms of the mathematical relationship among carrying capacity, biotic potential and the number of individuals in the population • explaining, quantitatively, the behaviour of populations, using different growth patterns; i.e., r- and K-strategies, J and S curves • describing the implications of the chaos theory for the study of biological systems, especially as they relate to population growth patterns.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that populations have characteristic growth patterns, and these changes can be expressed quantitatively; and by graphing and interpreting population growth data; designing and performing experiments demonstrating environmental influence; and researching the chaos theory, within the context of:
• graphing and interpreting population growth data on a variety of organisms • designing and performing an experiment to demonstrate the affect of environmental factors on population growth • researching the chaos theory, and hypothesizing its application to biological systems.	• analyzing the growth of human populations and comparing them with the naturally occurring populations of other species OR • evaluating the implications for natural systems inherent in the chaos theory OR • developing appropriate investigative strategies for dealing further with biological problems; e.g., risk/benefit analysis, cost/benefit analysis OR • any other relevant context.

CHEMISTRY 20–30

A. PROGRAM OVERVIEW

RATIONALE AND PHILOSOPHY

Chemistry is the study of matter and its changes. Through the study of chemistry, learners are given an opportunity to explore and understand the natural world and to become aware of the profound influence of chemistry in their lives. Learning is facilitated by relating the study of chemistry to what the learners already know, deem personally useful and consider relevant. Learning proceeds best when it originates from a base of concrete experiences presenting an authentic view of science in the context of chemistry. In Chemistry 20–30, students learn chemistry in relevant contexts and engage in meaningful activities. This facilitates the transfer of knowledge to new contexts. Students are encouraged to participate in lifelong learning about chemistry and to appreciate it as a scientific endeavour with practical impact on their own lives and on society as a whole.

Chemistry, as with all sciences, is an experimental discipline requiring creativity and imagination. Methods of inquiry characterize its study. In Chemistry 20–30, students further develop their ability to ask questions, investigate and experiment; to gather, analyze and assess scientific information; and to test scientific laws and principles and their applications. In the process, students exercise their creativity and develop their critical thinking skills. Through experimentation, and problem-solving activities that include the integration of technology and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The Chemistry 20–30 program places students at the centre. Students are active learners and will assume increased responsibility for their learning as they work through the program. A thorough study of chemistry is required to give students an understanding that encourages them to make appropriate applications of scientific concepts to their daily lives and prepares them for future studies in chemistry. Students are expected to participate actively in their own learning. An emphasis on the key concepts and principles of chemistry provides students with a more unified view of the sciences and a greater awareness of the connections among them.

These science learnings will take varying amounts of time to acquire, depending on the individual learning styles and abilities of students. While each course is designed for approximately 125 hours, instructional time can be modified to meet the individual needs of students. Some students will require more than 125 hours, while others will require less.

GOALS

The major goals of the Chemistry 20–30 program are:

- to develop in students an understanding of the interconnecting ideas and principles that transcend and unify the natural science disciplines
- to provide students with an enhanced understanding of the scientific world view, inquiry and enterprise
- to help students attain the level of scientific awareness essential for all citizens in a scientifically literate society
- to help students make informed decisions about further studies and careers in science
- to provide students with opportunities for acquiring knowledge, skills and attitudes that contribute to personal development.

Chemistry 20–30 is an academic program that helps students better understand and apply fundamental concepts and skills. The focus is on helping students understand the chemistry principles behind the natural events they experience and the technology they use in their daily lives. The program encourages enthusiasm for the scientific enterprise and develops positive attitudes about chemistry as an interesting human activity with personal meaning. It develops in students the knowledge, skills and attitudes to help them become capable of, and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities.

B. LEARNER EXPECTATIONS

GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for the specific learner expectations covered in section C. The general learner expectations are developed in two categories: *program* expectations and *course* expectations.

PROGRAM GENERAL LEARNER EXPECTATIONS

The *program* general learner expectations are broad statements of science attitudes, knowledge, skills and science, technology and society (STS) connections that students are expected to achieve in all of the senior high school science programs. These *program* general learner expectations are further refined through the *course* general learner expectations and then developed in specific detail through the study of individual units in each of Chemistry 20 and Chemistry 30. All expectations follow a progression from Science 10 through to Chemistry 30, and though listed separately, are meant to be developed in conjunction with one another, within a context.

ATTITUDES

Students will be encouraged to develop:

- enthusiasm for, and a continuing interest in, science
- affective attributes of scientists at work; such as, respect for evidence, tolerance of uncertainty, intellectual honesty, creativity, perseverance, cooperation, curiosity and a desire to understand
- positive attitudes toward scientific and technological skills involving process skills, mathematics, and problem solving
- open-mindedness and respect for the points of view of others
- sensitivity to the living and nonliving environment
- appreciation of the roles of science and technology in our understanding of the natural world.

KNOWLEDGE

Science Themes

Students will be expected to demonstrate an understanding of themes that transcend the discipline boundaries, and show the unity among the natural sciences, including:

- Change: how all natural entities are modified over time, how the direction of change might be predicted and, in some instances, how change can be controlled
- Diversity: the array of living and nonliving forms of matter and the procedures used to understand, classify and distinguish those forms on the basis of recurring patterns
- Energy: the capacity for doing work that drives much of what takes place in the Universe through its variety of interconvertible forms
- Equilibrium: the state in which opposing forces or processes balance in a static or dynamic way
- Matter: the constituent parts, and the variety of states of the material in the physical world
- Systems: the interrelated groups of things or events that can be defined by their boundaries and, in some instances, by their inputs and outputs.

SKILLS

Students will be expected to develop an ability to use thinking processes associated with the practice of science for understanding and exploring natural phenomena, problem solving and decision making. Students will also be expected to use teamwork, respect the points of view of others, make reasonable compromises, contribute ideas and effort, and lead when appropriate to achieve the best results. These processes involve many skills that are to be developed within the context of the program content.

Students will also be expected to be aware of the various technologies, including information technology, computer software and interfaces that can be used for collecting, organizing, analyzing and communicating data and information.

The skills framework presented here assumes that thinking processes often begin with an unresolved problem or issue, or an unanswered question. The problem, issue or question is usually defined and hypotheses formulated before information gathering can begin. At certain points in the process, the information needs to be organized and analyzed. Additional ideas may be generated—for example, by prediction or inference—and these new ideas, when incorporated into previous learning, can create a new knowledge structure. Eventually, an outcome, such as a solution, an answer or a decision is reached. Finally, criteria are established to judge ideas and information in order to assess both the problem-solving process and its outcomes.

The following skills are not intended to be developed sequentially or separately. Effective thinking is nonlinear and recursive. Students should be able to access skills and strategies flexibly; select and use skills, processes or technologies that are appropriate to the tasks; and monitor, modify or replace them with more effective strategies.

- Initiating and Planning
  - identify and clearly state the problem or issue to be investigated
  - differentiate between relevant and irrelevant data or information
  - assemble and record background information
  - identify all variables and controls
  - identify materials and apparatus required
  - formulate questions, hypotheses and/or predictions to guide research
  - design and/or describe a plan for research, or to solve a problem
  - prepare required observation charts or diagrams, and carry out preliminary calculations
- Collecting and Recording
  - carry out the procedure and modify, if necessary
  - organize and correctly use apparatus and materials to collect reliable data
  - observe, gather and record data or information accurately according to safety regulations; e.g., Workplace Hazardous Materials Information System (WHMIS), and environmental considerations
- Organizing and Communicating
  - organize and present data (themes, groups, tables, graphs, flow charts and Venn diagrams) in a concise and effective form
  - communicate data effectively, using mathematical and statistical calculations, where necessary
  - express measured and calculated quantities to the appropriate number of significant digits, using SI notation for all quantities
  - communicate findings of investigations in a clearly written report
- Analyzing
  - analyze data or information for trends, patterns, relationships, reliability and accuracy
  - identify and discuss sources of error and their affect on results

- identify assumptions, attributes, biases, claims or reasons
- identify main ideas

- Connecting, Synthesizing and Integrating
  - predict from data or information, and determine whether or not these data verify or falsify the hypothesis and/or prediction
  - formulate further, testable hypotheses supported by the knowledge and understanding generated
  - identify further problems or issues to be investigated
  - identify alternative courses of action, experimental designs, and solutions to problems for consideration
  - propose and explain interpretations or conclusions
  - develop theoretical explanations
  - relate the data or information to laws, principles, models or theories identified in background information
  - propose solutions to a problem being investigated
  - summarize and communicate findings
  - decide on a course of action

- Evaluating the Process or Outcomes
  - establish criteria to judge data or information
  - consider consequences and biases, assumptions and perspectives
  - identify limitations of the data or information, and interpretations or conclusions, as a result of the experimental/research/project/design process or method used
  - evaluate and suggest alternatives and consider improvements to the experimental technique and design, the decision-making or the problem-solving process
  - evaluate and assess ideas, information and alternatives

CONNECTIONS AMONG SCIENCE, TECHNOLOGY AND SOCIETY

Science, Technology and Society (STS)

Students will be expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationships among science, technology and society, including:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of processes or products based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

FURTHER READING

For a more detailed discussion on how to integrate thinking and research skills into the science classroom, refer to the publications: *Teaching Thinking: Enhancing Learning*, 1990 and *Focus on Research: A Guide to Developing Students' Research Skills*, 1990.

For further reading on integrating science, technology and society into the classroom, refer to the publication: *STS Science Education: Unifying the Goals of Science Education,* 1990.

COURSE GENERAL LEARNER EXPECTATIONS

The *course* general learner expectations are specific to each of Chemistry 20 and Chemistry 30 providing a bridge between the *program* general learner expectations and the specific learner expectations for each unit of study.

The attitudes expectations refer to those predispositions that are to be fostered in students. These expectations encompass attitudes toward science, the role of science and technology, and the contributions of science and technology toward society. The knowledge expectations are the major chemistry concepts in each course. The skills expectations refer to the thinking processes and abilities associated with the practice of science, including understanding and exploring natural phenomena, and problem solving. The connections among science, technology and society expectations focus on: the processes by which scientific knowledge is developed; the interrelationships among science, technology and society; and links each course to careers, everyday life and subsequent studies of chemistry.

Although itemized separately, the attitudes, knowledge, skills and STS connections are meant to be developed together within one or more contexts.

Chemistry 20–30

Attitudes

Students will be encouraged to:

- appreciate the role of empirical evidence and models in science, and accept the uncertainty in explanations and interpretations of observed phenomena
- value the curiosity, openness to new ideas, creativity, perseverance and cooperative hard work required of scientists, and strive to develop these same personal characteristics
- appreciate the role of science and technology in advancing our understanding of the natural world, be open-minded and respectful of other points of view when evaluating scientific information and its applications, and appreciate that the application of science and technology by humankind can have beneficial as well as harmful effects and can cause ethical dilemmas
- show a continuing interest in science, appreciate the need for computational competence, problem-solving and process skills when doing science, and value accuracy and honesty when communicating the results of problems and investigations
- value the need for safe handling, storing and disposing of chemicals and materials with care for the environment.

Chemistry 20

Students will be able to:

Knowledge

- apply the principles of energy and matter conservation to chemical systems undergoing change; and use direct evidence and generalizations to predict the outcomes of chemical change; and relate chemical change principles to a variety of reaction applications
- analyze physical, chemical and biological systems in terms of energy and matter forms, transfers, movement and conservation
- explain the interrelationship between energy and chemical changes to matter and how energy is either released or absorbed as chemical bonds are rearranged and new substances are formed; and describe the practical applications of exothermic and endothermic changes

- explain chemical changes to matter; and write balanced chemical equations to describe transformations and analyze them, quantitatively and qualitatively, to make predictions about the products formed or reactants consumed; and apply this knowledge to stoichiometric calculations in a variety of everyday and industrial situations

- describe solution systems, including acids, bases and gases, quantitatively and qualitatively, and relate their properties to their uses

- describe the diverse forms of matter, using models to illustrate bonding and structure, and using theories to explain the properties and behaviour of a variety of elements and organic and inorganic compounds and solutions, including acids, bases and gases

<u>Skills</u>

- perform investigations and tasks of their own and others' design that have a few variables and yield direct or indirect evidence; and provide explanations based upon scientific theories and concepts

- collect, verify and organize data into tables of their own design, and graphs and diagrams of others' design, using written and symbolic forms; and describe findings or relationships, using scientific vocabulary, notation, theories and models

- analyze and interpret data that yield straight- and curved-line graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and derive from graphs mathematical relationships among variables

- use mathematical language of ratio and proportion, numerical and algebraic methods, gravimetric and solution stoichiometry and unit analysis to solve single- and multi-step problems; and to communicate scientific relationships and concepts

<u>Connections Among Science, Technology and Society</u>

- apply cause and effect reasoning to formulate simple relationships for a given instance in which scientific evidence shapes or refutes a theory; and describe the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and explain the design and function of technological solutions to practical problems, using scientific principles; and relate the ways in which chemistry and technology advance one another, using appropriate and relevant examples

- explain for a given instance how science and technology are influenced and supported by society, and the responsibility of society, through chemistry and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Chemistry 20 to everyday life and to related and new concepts in subsequent studies of chemistry.

Chemistry 30

Students will be able to:

<u>Knowledge</u>

- apply the principles of energy and matter conservation to chemical systems undergoing change; and use direct and indirect evidence and theoretical knowledge to predict the outcomes of chemical change; and relate chemical change principles to a broad range of reaction applications

- analyze and evaluate biological, chemical and physical systems in terms of energy and matter forms, transfers, movement and conservation

- explain the interrelationship between energy and physical, chemical and nuclear changes to matter by describing how the rearrangement of bonds results in the release or absorption of energy; and evaluate society's production and use of energy from fossil fuels and nuclear fission

- analyze and explain, quantitatively and qualitatively, the transfer of electrons, and the energy and matter transformations that take place in electrochemical systems; and write balanced oxidation–reduction equations; and describe applications of oxidation–reduction reactions in electrochemical and electrolytic cells

- describe chemical equilibrium systems for acids, bases and gases, quantitatively and qualitatively, and describe some applications

- explain the Brønsted–Lowry concept of acids and bases; and, quantitatively and qualitatively, describe acid and base solutions in a variety of ways; and write and analyze reaction equations; and perform calculations and interpretations from titration data

Skills

- perform and evaluate investigations and tasks of their own and others' design that have multiple variables and yield direct or indirect evidence; and provide explanations and interpretations, using scientific theories and concepts

- collect, verify and organize data into tables, graphs and diagrams of their own design, using written and symbolic forms; and describe findings or relationships and make predictions, using scientific vocabulary, notation, theories and models

- analyze, interpret and evaluate data that yield straight- and curved-line graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and derive from graphs mathematical relationships among variables

- use mathematical language of ratio and proportion, numerical and algebraic methods, and unit analysis to solve multi-step, nonroutine problems; and communicate scientific relationships and concepts

Connections Among Science, Technology and Society

- apply cause and effect reasoning to formulate relationships for a range of instances in which scientific evidence shapes or refutes a theory; and explain the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and evaluate the design and function of technological solutions to practical problems, using scientific principles or theories; and relate the ways in which chemistry and technology advance one another, using appropriate and relevant examples

- explain and evaluate for a given instance, and from a variety of given perspectives, how science and technology are influenced and supported by society; and assess the ability and responsibility of society, through chemistry and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Chemistry 30 to everyday life and to related and new concepts in post-secondary studies of chemistry.

SPECIFIC LEARNER EXPECTATIONS

LEARNING CYCLE

The specific learner expectations consist of the knowledge, skills and attitudes that are to be addressed in Chemistry 20–30. The use of the learning cycle allows students to progress, from:

- an introduction framing the lesson in an STS connection relevant to the lives of the learners, and makes connections between past and present learning experiences, as well as anticipates activities to focus students' thinking on the learning outcomes of the activity

TO

- the experiential exploration of new content that provides students with a common base of experiences within which they identify and develop key concepts, processes and skills

THROUGH

- a hypothesis-building phase where concepts are developed to describe a particular aspect of their experiential exploration, and opportunities are provided to communicate their conceptual understanding, or demonstrate their skills or behaviours

TO

- an elaboration phase that extends understanding of key concepts and allows further opportunities to practise desired skills and problem-solving strategies

TO

- an application phase where the hypotheses, vocabulary and patterns previously developed are applied to new situations and related to key concepts and principles of science

TO

- a final evaluation of the significance of the new learning in an STS context to assess their understanding and abilities, and provide opportunities for evaluation of student progress toward achieving the curriculum standards.

In Chemistry 20–30, students examine phenomena in a variety of topics to show the relationships among all the sciences. Wherever possible, examples should be framed in the context of the learners' own experiences to enable them to make the connections between scientific knowledge and the society around them, the technology that societies have developed, and the nature of science itself.

PROGRAM OVERVIEW

The Chemistry 20–30 program emphasizes the science themes: *change, diversity, energy, equilibrium, matter* and *systems* as they relate to chemistry. These themes provide a means of showing the connections among the units of study in both courses of the program, and provide a framework for students to learn how individual sections of the program relate to the big ideas of science.

In addition to developing a solid understanding of fundamental science concepts and principles, Chemistry 20–30 has the goal of educating students about the nature of science and technology, and the interaction between chemistry and technology. Students must be aware of the tremendous impact of chemistry and associated technology on society, but at the same time, they must be aware of the roles and limitations of the chemistry sciences, science in general, and of technology in problem solving in a societal context.

CHEMISTRY 20

Chemical *change* and *matter* are the themes common to all the units in Chemistry 20. An understanding of the nature of *matter* and an analysis of its *changes* is essential for understanding what is happening and for predicting what will happen; control of *change* is essential for the design of technological *systems*. The principles of conservation of mass and *energy* help to predict and explain the *changes* that occur in a closed *system*. Chemistry 20 students are developmentally ready to begin defining *matter* in conceptual terms. Observations that provide evidence to support theories are stressed through experimentation and linking empirical and theoretical knowledge.

The major concepts allow connections to be drawn among the four units of the course and among all seven units in the two courses in the program.

Chemistry 20 consists of four units of study:

Unit 1: Matter as Solutions, Acids, Bases and Gases
Unit 2: Quantitative Relationships in Chemical Changes
Unit 3: Chemical Bonding in Matter
Unit 4: The Diversity of Matter: An Introduction to Organic Chemistry.

Each unit in Chemistry 20 uses a different context to investigate the nature of *matter*; to identify common patterns and the processes by which *matter* and *systems* are modified. Unit 1 focuses on the nature of *matter*, specifically solutions and gases, by examining their properties, identifying patterns and analyzing *changes* in these *systems*. In Unit 2, the quantitative relationships in chemical reaction *systems* are explored in predicting masses of substances reacted or produced as a result of chemical *change*. In Unit 3, models of the atom are extended to models of bonding as the properties of *matter* and theoretical explanations about its behaviour are linked. In Unit 4, examples of the *diverse* forms of organic compounds are investigated and compared with inorganic *matter*. *Change* as it relates to chemical reactions of organic compounds in living and nonliving systems is also examined.

CHEMISTRY 30

The themes of *change*, *energy* and *systems* are central in Chemistry 30. *Equilibrium* and *matter* are subordinate themes that are also addressed. The components of a *system*, which may be a collection of substances or processes, influence each other by the transfer of *energy* and *matter*. Changes to one part result in *changes* to other parts of the system. In a system at *equilibrium*, opposing reactions are balanced.

The major concepts allow connections to be drawn among the three units of the course and among all seven units in the two courses in the program.

Chemistry 30 consists of three units of study:

Unit 1: Thermochemical Changes
Unit 2: Electrochemical Changes
Unit 3: Equilibrium, Acids and Bases in Chemical Changes.

Chemistry 30 expands upon the concepts and skills introduced in Science 10 and Chemistry 20. Each unit in Chemistry 30 uses a different context to investigate the nature of chemical *change*. The themes are addressed using examples from inorganic and organic chemistry to emphasize the unity of science. *Energy,* as it relates to chemical *change,* is the focus of Unit 1. *Energy* as heat is most commonly absorbed or released in chemical reactions. Thermochemistry is the study of these heat *changes*. *Changes* in physical and nuclear *systems* are briefly explored for comparison. In Unit 2, *changes* in electrochemical *systems* are examined, oxidation–reduction reactions are analyzed, and the *energy* and *matter* involved are quantified. In Unit 3, the focus is on chemical *systems* at *equilibrium*. Few chemical reactions proceed in only one direction; most are somewhat reversible. Chemical *systems* involving acids and bases are studied as examples of chemical *changes* at *equilibrium*.

CHEMISTRY 20

UNIT 1
MATTER AS SOLUTIONS, ACIDS, BASES AND GASES

OVERVIEW

Science Themes: *Change, Matter* and *Systems*

In Unit 1, students gain an insight into the nature of *matter* through an investigation of *change* in the context of solutions, including acids, bases and gases. Viewing models of *matter* as *systems* undergoing *change* aids in their understanding of the underlying structure of *matter.*

This unit builds on Science 7, Unit 4: Temperature and Heat Measurement; Science 8, Unit 1: Solutions and Substances; Science 9, Unit 5: Chemical Properties and Changes; Science 10, Unit 1: Energy from the Sun, Unit 3: Energy and Matter in Chemical Change, and on Unit 4: Change and Energy. It provides students with a foundation for the study of stoichiometry and bonding in Chemistry 20 and electrochemistry, acids and bases in Chemistry 30.

The three **major concepts** developed in this unit are:

- solutions are homogeneous mixtures of pure substances
- acids and bases have an affect on aqueous *systems*
- a model of the gaseous state of *matter* provides insight into molecular behaviour.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording data according to safety and environmental considerations
- organizing and communicating data
- evaluating the process or outcomes of the design of investigations into the properties of and *changes* to *matter.*

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop a questioning attitude and a desire to understand more about *matter*
- appreciate that scientific evidence is the foundation for generalizations and explanations about *matter*
- develop an awareness of the importance of water as a medium for chemical *change*
- value the need for safe handling, storing and disposing of chemicals and materials
- respect the usefulness of models and theories that are used to explain natural phenomena relating to the behaviour of gases
- develop an interest in the role of solutions, acids, bases and gases in daily life
- appreciate that our understanding of *matter* has been enhanced by the evidence obtained from the application of technology, particularly instruments for making measurements and managing data.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Solutions are homogeneous mixtures of pure substances.	• the composition of solutions can be accurately described, by extending from Science 8, Unit 1, and Science 10, Unit 1 and Unit 3, the meaning of solute, solvent, dissolving, solution, solubility and the properties of water, and by: • providing examples, from living and nonliving systems, of how dissolving substances in water is often a prerequisite for chemical change • differentiating between electrolytes and nonelectrolytes • defining concentration in terms of molarity (moles per litre of solution) • using simple calculations to show different ways of expressing concentration; e.g., per cent by mass and volume, parts per million (ppm) • outlining the steps required to prepare a solution and a dilution of a solution • describing an equilibrium system in a saturated solution in terms of equal rates of dissolving and crystallization.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*

Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:

- using a simple conductivity apparatus to perform an experiment to identify solutions
- using a balance and volumetric glassware to prepare solutions of specified concentration
- performing an experiment to determine the identity of an ion, using simple qualitative tests, including solution colour, flame tests and solubility
- writing dissociation/ionization equations for dissolved strong acids and ionic compounds
- calculating, from empirical data, the concentration of solutions in moles per litre of solution and determining mass or volume from such concentrations
- calculating, from empirical data, the concentration of diluted solutions, and the quantities of a solution and water to use when diluting
- using empirical data and dissociation equations to calculate the concentration of ions in a solution.

Students should be able to demonstrate the interrelationships among science, technology and society, by:

- understanding solutions and their significance in living and nonliving systems; and ways of expressing and calculating concentration; and preparing solutions, using qualitative tests to identify solutions and ions in solution, within the context of:
  - providing examples of how solutions and solution concentrations are applied in products and processes, in scientific studies and in daily life; and comparing the ways in which concentrations of solutions are expressed in the chemistry laboratory, in household products and in environmental studies

    OR

  - explaining the role of concentration in risk/benefit analysis and the significance of biological magnification in increasing the concentration of substances within ecosystems in terms of protecting the environment from harm to ensure quality of life for future generations

    OR

  - evaluating the risk involved in safe handling, storing and disposing of solutions in common use in the laboratory and in the home

    OR

  - investigating the application of the scientific principles of qualitative analysis in the practice of chemistry; e.g., careers in forensic science

    OR

  - any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Acids and bases have an effect on aqueous *systems*.	• acids and bases affect the chemistry of aqueous systems, by extending from Science 9, Unit 5, and Science 10, Unit 3, the properties, formulas and names of acids and bases, and by: • defining acids and bases, ionization and neutralization, empirically and theoretically, based on Arrhenius' concepts • defining pH in terms of whole number powers of 10 • describing the relationship between pH and hydrogen ion concentration; i.e., a change of 1 in the pH value is equivalent to a ten-fold change in the hydrogen ion concentration • calculating whole number pH values from hydrogen ion concentration, and hydrogen ion concentration from whole number pH values.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that acids and bases affect the chemistry of aqueous systems by defining acids and bases, by differentiating among acidic, basic and neutral solutions, using simple tests, writing ionization equations, and calculating the concentrations of hydrogen and hydroxide ions in solution and pH, within the context of:
• using indicators, pH and conductivity to perform experiments to differentiate among acidic, basic and neutral solutions • calculating concentrations of H^+ or OH^- for strong acids and bases • constructing a table comparing pH and hydrogen ion concentration in order to illustrate that as the hydrogen ion concentration increases, the pH decreases.	• providing examples of processes and products that use knowledge of acid and base chemistry; e.g., pulp and paper, car batteries, food preparation, cleaning aids OR • identifying some everyday processes and products that require knowledge of how to handle acids and bases; e.g., sulfuric acid in car batteries, never mixing bleach with household cleaners; treating accidental acid or base spills, using neutralization and dilution OR • assessing, qualitatively, the risks and benefits of transporting acidic and caustic substances in populated areas in terms of the need to protect the environment to ensure society's safety and quality of life for future generations OR • relating the concept of pH to its application in describing solutions encountered in everyday life and comparing the pH scale to others, like the Richter scale for measuring the intensity of earthquakes OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. A model of the gaseous state of *matter* provides insight into molecular behaviour.	• the behaviour of gases has been extensively described, and relationships quantified, by extending from Science 7, Unit 4, the concept of temperature and from Science 10, Unit 4, the kinetic molecular theory and how it accounts for the properties of solids, liquids and gases, and by: • performing calculations, using Boyle's and Charles' laws, and illustrating how they are related to the combined gas law • relating Boyle's, Charles' and Avogadro's laws to the ideal gas law • converting between the Celsius and Kelvin temperature scales and expressing atmospheric pressure in a variety of ways; e.g., mm of Hg, atm, kPa • performing calculations based on the ideal gas equation, $PV=nRT$, under a variety of conditions; e.g., standard temperature and pressure (STP), standard ambient temperature and pressure (SATP) • describing the behaviour of real and ideal gases, in terms of the kinetic molecular theory.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the behaviour of gases by relating the gas laws proposed by Boyle, Charles and Avogadro to the ideal gas law, describing the behaviour of real and ideal gases in terms of the kinetic molecular theory; and by drawing and interpreting graphs that relate pressure and temperature to gas volume; designing, performing and evaluating experiments to illustrate the gas laws, and carrying out calculations based on the gas laws, within the context of:
• drawing and interpreting graphs of experimental data that relate pressure and temperature to gas volume • designing and performing an experiment to illustrate the gas laws, which identify and control variables • performing and evaluating an experiment to determine molar mass from gaseous volume • using empirical data to do calculations based on the ideal gas law.	• providing examples of processes and products from daily life that illustrate the application of the properties of gases; e.g., breathing, olfaction, weather, scuba diving, ammonia fertilizer, internal combustion engine, steam turbine, hot air balloon, automobile air bag OR • describing, from a historical perspective, the central role of experimentation, and the development of technologies capable of precise measurement in the formulation of the gas laws OR • evaluating, in terms of the influence of the needs, interests and financial support of society on scientific and technological research, the advantages and disadvantages of using compressed gases as fuels; e.g., hydrogen, methane, propane OR • any other relevant context.

UNIT 2
QUANTITATIVE RELATIONSHIPS IN CHEMICAL CHANGES

OVERVIEW

Science Themes: *Change* and *Systems*

In Unit 2, students focus on chemical *change* and the quantitative relationships contained in the balanced chemical equation. Students are required to use mathematical manipulation and stoichiometric principles to predict quantities of substances consumed or produced in chemical reaction *systems*. This unit builds on Science 10, Unit 3: Energy and Matter in Chemical Change; and Chemistry 20, Unit 1: Matter as Solutions, Acids, Bases and Gases.

This unit provides students with a foundation for the study of quantitative relationships in thermochemical, electrochemical, and acid and base reactions in Chemistry 30.

The two **major concepts** developed in this unit are:

- balanced chemical equations indicate the quantitative relationships among reactants and products involved in chemical *changes*
- the relationships between amounts of reactants and products in chemical *changes* are used in quantitative analysis.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data related to quantitative relationships in chemical *change*.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science.

ATTITUDES

Students will be encouraged to:

- develop a positive attitude toward mathematical and scientific process skills
- appreciate the importance of careful laboratory techniques and precise calculations for obtaining accurate results
- develop confidence in their ability to reason mathematically
- value the role of technology, such as calculators and balances, in problem solving
- develop an awareness of the relationship between chemical principles and applications of chemistry
- appreciate the need for empirical evidence when interpreting observed phenomena.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Balanced chemical equations indicate the quantitative relationships among reactants and products involved in chemical *changes*.	• the mole ratios in balanced chemical reaction equations provide quantitative information about the substances involved, by extending from Science 10, Unit 3, the balancing of equations and the meaning of molar mass, and from Chemistry 20, Unit 1, the properties of solutions and gases, and by: • predicting the product(s) of a chemical reaction, based upon the reaction type • analyzing chemical equations in terms of atoms, molecules, ionic species and moles • identifying spectator ions in reactions taking place in aqueous solution • using gravimetric, solutions and gas stoichiometry to predict quantities of reactants/products involved in chemical reactions • using estimation and unit analysis in stoichiometric calculations • explaining stoichiometric calculations, using chemical principles.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that balanced chemical equations indicate quantitative relationships between reactants and products by analyzing chemical equations, performing and explaining stoichiometric predictions; and by performing experiments to test the assumptions contained in stoichiometric methods, within the context of:
• writing and balancing net ionic chemical equations to represent reactions taking place in aqueous solution • performing experiments to test the validity of assumptions contained in stoichiometric methods, by, for example, predicting reaction results, then measuring the amount of product obtained from a reaction, and calculating the per cent yield.	• analyzing, using stoichiometric and chemical principles, the chemical reactions involved in various industrial and commercial processes and products; e.g., fertilizers, production of sodium and chlorine in the Downs cell, Haber–Bosch production of ammonia, combustion of fuels, water treatment, inflation of automobile air bags OR • discussing the central role of experimental evidence and the way in which scientific theories may be supported, modified or refuted by, for example, citing Lavoisier's role in disputing the caloric theory OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The relationships between amounts of reactants and products in chemical *changes* are used in quantitative analysis.	• stoichiometric methods are important in quantitative analysis, by extending from Chemistry 20, Unit 1, solution concentrations, and by: • differentiating between quantitative and qualitative analysis • using evidence from titration to determine the concentration of a solution • using evidence from precipitation reactions to determine the concentration of ions in solutions, using gravimetric procedures • identifying limiting species in chemical reactions, and calculating predicted and experimental yields • explaining quantitative analysis, using chemical principles; e.g., conservation of mass in a chemical change.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the relationships among amounts of reactants and products in chemical changes, limiting species, predicted and experimental yields; and by designing, performing and evaluating experiments and carrying out calculations, based on quantitative analysis, to determine the concentration of a solution, within the context of:
• using appropriate glassware and equipment to perform a titration experiment to determine the concentration of a solution • performing and evaluating an experiment, based on a precipitation reaction, to determine the concentration of a solution • designing, performing and evaluating an experiment based on such methods as crystallization, filtration or titration, to determine the concentration of a solution.	• explaining the interrelationship of science and technology, using examples of how stoichiometry is applied; e.g., industries use stoichiometric calculations to determine the amount of raw materials needed to produce products with a minimum of waste OR • describing industrial, commercial and household processes and products, and associated careers, that require a knowledge of quantitative analysis OR • evaluating the significance of specific by-products from industrial, commercial and household applications of chemical reactions in terms of using technology to improve per cent yield, decrease waste and reduce environmental impact; e.g., recovering $SO_2(g)$ from smokestacks, installing catalytic afterburners on cars, finding alternatives to chlorine for disinfecting and bleaching OR • any other relevant context.

UNIT 3
CHEMICAL BONDING IN MATTER

OVERVIEW

Science Theme: *Matter*

The major focus of this unit is to relate theories about bonding to the properties of *matter* and to develop explanations and descriptions of structure and bonding through scientific models.

This unit builds on Science 10, Unit 3: Energy and Matter in Chemical Change. This unit provides an introduction to Chemistry 30, Unit 1: Thermochemical Changes, and Unit 2: Electrochemical Changes.

The **major concept** developed in this unit is:

- chemical bonding in *matter* results in the formation of compounds.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- analyzing
- connecting, synthesizing and integrating while investigating bonding in *matter*.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- develop curiosity about the nature of chemical bonding
- appreciate the usefulness of models and theories in helping to explain the structure and behaviour of *matter*
- value the need for safe handling, storing and disposing of chemicals and materials
- tolerate the uncertainty in explanations about the nature of *matter*
- appreciate the restricted nature of evidence when interpreting observed phenomena.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Chemical bonding in *matter* results in the formation of compounds.	• theories about bonding propose that chemical bonds involve electron transfer or sharing, by extending from Science 10, Unit 3, the simple model of the atom, the organization of the periodic table and the differences in properties of ionic and covalent compounds, and by: • defining a chemical bond as resulting from the simultaneous attraction of electrons by two atomic nuclei • describing bonding as a continuum ranging from complete electron transfer to equal sharing of electrons • defining valence electron, electronegativity, electron pairing, ionic bond and covalent bond • determining the polarity of a molecule based on simple structural shapes and unequal charge distribution • explaining why formulas for ionic compounds refer to the simplest whole number ratio of ions that result in a net charge of zero, while the formulas for molecular compounds refer to the number of atoms of each constituent element • comparing intermolecular forces with intramolecular bonding, in terms of strength and species involved • explaining, in simple qualitative terms, the energy changes of bond breaking and bond formation and relating this to why some changes are exothermic while others are endothermic • describing the information contained in the activity series and how it was developed • defining oxidation as a loss of electrons and reduction as a gain of electrons • relating the terms oxidation and reduction to bonds forming between metals and nonmetals; e.g., corrosion.

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:

- building models depicting the structure of ionic solids and simple covalent molecules
- using the periodic table as a tool for predicting the formation of ionic and molecular compounds
- writing half-reactions for the formation of simple ionic compounds, showing oxidation of metals and reduction of nonmetals; then balancing for charge and combining into a single equation; e.g.,

$$2Na_{(s)} \rightarrow 2Na^{+} + 2e^{-}$$
$$Cl_{2(g)} + 2e^{-} \rightarrow 2Cl^{-}$$
$$\overline{}$$
$$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$$

- designing and performing an experiment to investigate the reactivity of various metals with water, oxygen and dilute acids, to develop an activity series
- using data contained in the periodic table and the activity series to predict bonding and electron transfer between elements
- drawing electron dot diagrams of atoms and molecules, writing structural formulas for compounds, and using Lewis structures to predict bonding in simple molecules.

STS CONNECTIONS

Students should be able to demonstrate the interrelationships among science, technology and society, by:

- understanding that chemical bonds involve electron transfer or sharing, by comparing and contrasting intermolecular and intramolecular bonding; building models of compounds, using the periodic table and activity series to predict bonding; designing and performing an experiment to investigate the activity series of metals, and drawing electron dot diagrams and Lewis structures, within the context of:
  - analyzing the functioning of everyday processes and products in which ionic and covalent compounds are significant; for example, investigating the composition of household products, combustion reactions and life processes

    OR
  - relating the chemical principles embedded in bonding theories, oxidation and reduction, and the activity series to terms such as "precious" metal, rusting, stability and reactivity

    OR
  - outlining the limitations of bonding theories, by; for example, investigating bonding in metals and ceramics, and investigating the concept of resonance

    OR
  - describing the central role of experimental evidence in the accumulation of knowledge, by relating the properties; e.g., melting and boiling points, solubility, density and viscosity, of common substances to their predicted intermolecular and intramolecular bonding

    OR
  - interrelating the applications and properties of such modern materials as semiconductors, ceramics and composites, explaining how science and technology interact in the production and distribution of useful materials; and explaining the influence of the needs, interests and financial support of society on scientific and technological research

    OR
  - any other relevant context.

UNIT 4
THE DIVERSITY OF MATTER: AN INTRODUCTION TO ORGANIC CHEMISTRY

OVERVIEW

Science Themes: *Change, Diversity* and *Matter*

In this unit, students learn more about the *diversity* of *matter* from specific examples of organic compounds. They are introduced to the chemical and physical properties of organic compounds, the general nomenclature and formulas for hydrocarbon categories, their significant derivatives and reactions. Another theme of the unit is *change* as it relates to chemical reactions involving organic compounds in living and nonliving systems.

This unit builds on Science 9, Unit 5: Chemical Properties and Changes; Science 10, Unit 3: Energy and Matter in Chemical Change; and Chemistry 20, Unit 3: Chemical Bonding in Matter. The unit prepares students for the integrated approach to organic and inorganic chemistry that is taken in Chemistry 30.

The two **major concepts** developed in this unit are:

- organic compounds are a common form of *matter*
- the chemical *changes* of organic compounds are many and *diverse*.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- organizing and communicating
- connecting, synthesizing and integrating in the investigation of organic compounds and their reactions.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop an appreciation of the *diversity* of organic compounds and their significance to daily life
- appreciate that science and technology provide many useful products
- value the need for safe handling, storing and disposing of chemicals and materials
- develop an awareness that, as a result of chemistry, synthetic compounds of great benefit to society have been produced
- develop an awareness of the need for open-mindedness in evaluating environmental issues
- respect the contributions and limitations of scientific and technological knowledge to societal decision making.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Organic compounds are a common form of *matter*.	• organic compounds have distinguishing characteristics, by extending from Chemistry 20, Unit 3, ionic covalent bonding, and by: • comparing organic and inorganic compounds in terms of the presence of carbon, bonding and related properties, and natural sources • describing the composition and structural formulas for aliphatic (including cyclic) and aromatic hydrocarbons • providing names and formulas for examples of the organic compounds described above • defining and giving examples of structural isomerism • identifying alcohols, aldehydes, ketones, carboxylic acids, halogenated hydrocarbons, amines, amides and esters from their IUPAC names and the functional groups in their structural formulas.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that organic compounds have distinguishing characteristics by comparing them with inorganic compounds; describing the composition of and providing names and structural formulas for various hydrocarbons and their derivatives; and by investigating the physical and chemical properties of representative examples of organic compounds and building models depicting the structures of simple examples, within the context of:
• using safe substances and procedures to perform an experiment to investigate the physical and chemical properties of representative examples of organic compounds • gathering data to compare the properties of a pair of organic isomers • building molecular models depicting the structures of simple organic compounds.	• comparing examples of organic and inorganic compounds, where they are found and how they are used in processes and products common to everyday life OR • explaining different conventions of nomenclature in a historical and cultural context OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The chemical *changes* of organic compounds are many and *diverse*.	• organic compounds undergo a variety of chemical reactions, by extending from Science 9, Unit 5 and Science 10, Unit 3, chemical change, and by: • defining and giving examples of addition, substitution, elimination, esterification and combustion reactions of hydrocarbons • writing and balancing chemical equations for the reactions described above • defining, outlining structures, and providing examples of monomers, polymers and polymerization in living and nonliving systems; e.g., proteins, carbohydrates, plastics • comparing reactions of organic compounds in living and nonliving systems; e.g., the oxidation of carbohydrates and the combustion of fuels • comparing hydrocarbon cracking and reforming.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that organic compounds undergo a variety of chemical changes by defining, giving examples of and writing chemical equations for various reactions; and by synthesizing an organic compound in the laboratory and building models to depict polymerization, within the context of:
• building models depicting polymerization • synthesizing an organic compound; e.g., an alcohol, an ester, a polymer, a soap.	• analyzing common polymers in terms of chemical composition and structure; e.g., paper, plastics, fibres, foods, found in the home, school and community OR • describing the petrochemical industry in Alberta and investigating career opportunities related to organic chemistry OR • assessing the positive and negative effects of synthetically produced organic compounds, recognizing that the development of these products has played a major role in quality of life and standard of living but that a practical solution to related social and environmental problems often requires a compromise between competing priorities OR • any other relevant context.

CHEMISTRY 30

UNIT 1
THERMOCHEMICAL CHANGES

OVERVIEW

Science Themes: *Change, Energy* and *Systems*

In this unit, students study *energy* as it relates to physical, chemical and nuclear *changes* and quantify the energy involved in thermochemical *systems.*

This unit builds on Science 9, Unit 3: Heat Energy: Transfer and Conservation; Science 10, Unit 1: Energy from the Sun, Unit 3: Energy and Matter in Chemical Change, Unit 4: Change and Energy; and Chemistry 20, Unit 2: Quantitative Relationships in Chemical Changes, and Unit 3: Chemical Bonding in Matter. This unit prepares students for post-secondary studies in related areas.

The **major concept** developed in this unit is:

- there are *energy changes* associated with *changes* to *matter*.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing
- connecting, synthesizing and integrating
- evaluating the process or outcomes of investigations of *energy changes.*

The **STS connections** in this unit illustrate:

- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop an interest in the *energy* transformations happening around them
- appreciate the usefulness of computational competence and problem-solving skills as they relate to *energy*
- value the need for accuracy and precision in data collection related to *energy*
- develop a sense of responsibility toward the use of *energy*
- develop an interest in global *energy* issues and the effectiveness of local activities in contributing to the solution of problems related to *energy*
- appreciate the need to balance long-term *energy* and environmental objectives with various societal needs
- appreciate the significance and meaning of various solutions to a problem.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. There are *energy changes* associated with *changes* to *matter*.	• energy changes can be measured and quantified, by extending from Science 9, Unit 3, the concepts of heat and temperature and Science 10, Unit 1 and Unit 4, the law of conservation of energy, the laws of thermodynamics, definitions for kinetic and potential energy, heat of fusion and calculations involving temperature and phase changes in water, based on $q=mc\Delta t$, as well as extending from Chemistry 20, Unit 3, the meaning of bond dissociation energy, exothermic and endothermic change, and by: • explaining what is meant by the energy change of a system in terms of heating and cooling, thermal equilibrium, temperature change, phase change, forces between particles, particle movement and heat content • writing balanced reaction equations that include the energy change • using and interpreting change in enthalpy (ΔH) notation for communicating energy changes • explaining that catalysts provide an alternative pathway for chemical changes without affecting the net amount of energy produced or absorbed • defining molar enthalpy/change, including the heats of phase, chemical and nuclear change • using Hess's law to derive equations for energy changes • using a standard heats of formation table to predict heat of reaction for a chemical change • explaining how energy stored as potential energy in the chemical bonds of fossil fuels originates in the Sun and is converted by the process of photosynthesis in living plants, represented simply as: $6CO_{2(g)}+6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(s)}+6O_{2(g)}$ • comparing the combustion of fuels to cellular respiration, represented by the simple equation: $C_6H_{12}O_{6(s)}+6O_{2(g)} \rightarrow 6CO_{2(g)}+6H_2O_{(l)}$ • comparing phase, chemical and nuclear changes in terms of the magnitudes of the energy involved • providing simple, qualitative explanations based on intermolecular forces, chemical bonds and nuclear forces for the energy changes that occur during phase, chemical and nuclear changes to matter • recognizing nuclear fission and fusion reactions.

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:

- drawing and interpreting energy diagrams based on experimental data; e.g., heating curves and potential energy graphs for phase, chemical and nuclear changes
- performing and evaluating experiments to determine the molar enthalpy change of physical and chemical changes to matter
- performing calculations based on empirical data gathered from experiments demonstrating energy changes associated with physical and chemical changes to matter
- designing an experimental procedure to compare the molar enthalpy change of burning two or more fuels
- designing and constructing a heating device, and calculating its efficiency.

STS CONNECTIONS

Students should be able to demonstrate the interrelationships among science, technology and society, by:

- understanding that the energy changes associated with changes to matter can be measured and quantified by explaining the energy change of a system; providing simple, qualitative explanations for energy changes in phase, chemical and nuclear changes; performing calculations related to physical and chemical changes to matter; and by drawing and interpreting energy diagrams; and designing, performing and evaluating experiments to determine molar enthalpies and energy efficiency, within the context of:
  - providing examples of personal reliance on the chemical potential energy of matter; e.g., of fuels and identifying and evaluating ways of using energy more efficiently in the home and community in order to use natural resources judiciously to ensure adequate supplies for future generations

    OR
  - providing examples of how catalysts play a role in many important chemical and biochemical processes; e.g., enzymes in cell processes, catalysts in reducing air pollution

    OR
  - illustrating the economic importance of fossil fuels, with examples from the petroleum and petrochemical industries in Alberta; analyzing, using chemical principles, the refining of hydrocarbons; and investigating careers related to the energy industry

    OR
  - evaluating different fuels from the perspective of economic and environmental impact; and researching and analyzing alternative energy sources, in terms of the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations

    OR
  - assessing, qualitatively, the risks and benefits of relying on fossil fuels or nuclear reactions as energy sources, considering the limitations of scientific knowledge and technology in societal decision making

    OR
  - any other relevant context.

UNIT 2
ELECTROCHEMICAL CHANGES

OVERVIEW

Science Themes: *Change, Energy, Matter* and *Systems*

In this unit, students study electrochemical *changes,* analyzing the *matter* and *energy changes* within a *system.*

This unit builds on Science 9, Unit 4: Electromagnetic Systems; Science 10, Unit 3: Energy and Matter in Chemical Change; Chemistry 20, Unit 2: Quantitative Relationships in Chemical Changes, and Unit 3: Chemical Bonding in Matter. This unit prepares students for post-secondary studies in related areas.

The two **major concepts** developed in this unit are:

- many chemical *changes* involve the transfer of electrons
- *energy* is involved in electrochemical *changes.*

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing
- connecting, synthesizing and integrating
- evaluating the process or outcomes of investigations of electrochemical *change.*

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop an interest in oxidation–reduction reactions that occur in everyday life
- appreciate the creativity and perseverance required to develop workable solutions to problems
- develop a willingness to try various problem-solving strategies, and risk being wrong
- value the contributions of the technological innovations of electrochemistry to quality of life
- develop an awareness that the application of technology by human societies can have beneficial and harmful effects on biological *systems*
- appreciate the multidimensional nature of science, technology and society issues.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Many chemical *changes* involve the transfer of electrons.	• oxidation–reduction reactions involve a transfer of electrons, by extending from Science 10, Unit 3, the structure of the atom and from Chemistry 20, Unit 3, the meanings for electronegativity, oxidation–reduction and the activity series, and by: • defining the terms: oxidizing agent, reducing agent, oxidation number, half-reaction, auto-oxidation (disproportionation) • differentiating between oxidation–reduction reactions and other reactions that do not involve oxidation–reduction by identifying half-reactions and changes in oxidation number • identifying electron transfer, oxidizing agents and reducing agents in oxidation–reduction reactions • writing and balancing equations for oxidation–reduction reactions: – using half-reaction equations obtained from a standard reduction potential table – developing simple half-reaction equations from information provided about oxidation–reduction changes – assigning oxidation numbers to the species undergoing chemical change • describing oxidation–reduction in simple biochemical processes; e.g., cellular respiration of glucose to carbon dioxide, $C_6H_{12}O_{6(s)}+6O_{2(g)}\rightarrow 6CO_{2(g)}+6H_2O_{(l)}$; photosynthesis in green plants, $6CO_{2(g)}+6H_2O_{(l)}\rightarrow C_6H_{12}O_{6(s)}+6O_{2(g)}$ • comparing oxidation–reduction reactions in living and nonliving systems.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that many chemical changes involve a transfer of electrons by defining terms related to oxidation–reduction; identifying, writing and balancing equations for oxidation–reduction reactions, calculating unknown quantities from oxidation–reduction titration reactions; and by designing, performing and evaluating experiments for deriving a simple reduction table and testing predictions about oxidation–reduction, within the context of:
• comparing the relative strengths of oxidizing and reducing agents from empirical data • designing, performing then evaluating an experiment for deriving a simple reduction table • selecting and correctly using the appropriate equipment to perform an oxidation–reduction titration experiment • performing calculations to determine quantities of substances involved in oxidation–reduction reactions, by using data from titration experiments.	• analyzing, as an example of the functioning of products and processes based on scientific principles, oxidation–reduction reactions that occur in everyday life; e.g., corrosion, metallurgy, respiration, photosynthesis; identifying half-reactions, oxidizing and reducing agents OR • analyzing, as an example of the functioning of processes and products based on scientific principles, oxidation–reduction reactions used in industry and commercially; e.g., pulp and paper and textile bleaching, water treatment, food processing; identifying half-reactions, oxidizing and reducing agents OR • investigating the use of technology to solve practical problems related to corrosion OR • relating oxidation–reduction reactions to global environmental problems, such as the production of greenhouse gases and acid rain OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. *Energy* is involved in electrochemical *changes.*	• electrochemical (Voltaic) cells operate on the energy of spontaneous oxidation–reduction reactions, while electrolytic cells require electrical energy to cause nonspontaneous oxidation–reduction reactions to occur, by extending from Science 9, Unit 4, the design of a wet cell and from Chemistry 20, Unit 2, qualitative relationships in chemical changes, and by: • defining and identifying, on diagrams of electrochemical (Voltaic) and electrolytic cells, the following: anode, cathode, anion, cation; as well as salt bridge/porous cup and external circuit for the former and power supply for the latter • predicting and writing balanced equations for reactions at the anode and the cathode of electrochemical (Voltaic) and electrolytic cells recognizing that predictions and observations do not always concur; e.g., the production of chlorine gas from the electrolysis of brine • identifying, on diagrams of electrochemical (Voltaic) and electrolytic cells, the flow of electrons, the migration of anions and cations, mass and colour changes, formation of gases, and precipitates, at the electrodes • defining standard reduction potential and explaining how the values are all relative to E° = 0.00 V set for the standard hydrogen electrode • calculating standard cell potential values for oxidation–reduction reactions • predicting the spontaneity or nonspontaneity of oxidation–reduction reactions on the basis of calculated standard cell potential values and relative positions of half-reaction equations on a standard reduction potential table • performing calculations to determine quantities of mass, volume, concentration, current and time in single electrochemical (Voltaic) and single electrolytic cells.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:

- constructing, observing and describing an electrolytic cell, comparing predictions and observations
- designing, constructing and measuring the standard cell potential of an electrochemical (Voltaic) cell, comparing predictions and observations
- evaluating experimental designs for electrochemical (Voltaic) and electrolytic cells, identifying limitations and suggesting improvements and alternatives
- using a standard reduction potential table as a tool in predicting the spontaneity of oxidation–reduction reactions and their products
- performing an experiment to test predictions about oxidation–reduction reactions with regard to spontaneity, products and standard cell potential values.

STS CONNECTIONS

Students should be able to demonstrate the interrelationships among science, technology and society, by:

- understanding electrochemical (Voltaic) and electrolytic cells by identifying and defining their important features on a diagram; predicting and writing balanced equations for reactions that occur at the anode and cathode, and performing calculations to determine quantities of products formed in them; and by designing, constructing, observing and describing electrochemical (Voltaic) and electrolytic cells, within the context of:
  - analyzing the ways in which science advances technology and technology advances science in the applications of electrochemical (Voltaic) and electrolytic cells; e.g., batteries, electroplating industries, refining metals from their ores, and sanitizing swimming pools

    OR

  - comparing and contrasting the energy costs of refining metals from their ores with that of recycling metals, and outlining the process by which commonly used metal-based products; e.g., aluminum or "tin" cans, are recycled in the community as an example of society taking the responsibility to protect the environment and use natural resources judiciously to ensure quality of life for future generations

    OR

  - assessing the economic importance of batteries to modern society, predicting their future prominence; for example, in transportation; investigating the issue of disposing of used batteries, and proposing alternative solutions to this problem

    OR

  - any other relevant context.

UNIT 3
EQUILIBRIUM, ACIDS AND BASES IN CHEMICAL CHANGES

OVERVIEW

Science Themes: *Change, Equilibrium* and *Systems*

In this unit, the concept that *change* eventually attains equilibrium is expanded to a quantitative treatment in reaction *systems* involving ideal gases and acid and base solutions. Students apply stoichiometric methods to titration experiments, further explore indicators and are introduced to buffer *systems.*

This unit builds on Science 8, Unit 1: Solutions and Substances; Science 9, Unit 5: Chemical Properties and Changes; Science 10, Unit 3: Energy and Matter in Chemical Change; Chemistry 20, Unit 1: Matter as Solutions, Acids, Bases and Gases, and Unit 2: Quantitative Relationships in Chemical Changes. This unit prepares students for post-secondary studies in related areas.

The three **major concepts** developed in this unit are:

- there is a balance of opposing reactions in chemical *equilibrium systems*
- acid and base *systems* are quantitatively and qualitatively described
- acid–base chemistry involves proton transfer.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing
- connecting, synthesizing and integrating
- evaluating the process or outcomes of investigations of *equilibrium*, acids and bases.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the limitations of scientific knowledge and technology
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the usefulness of the mathematical model in describing chemical *equilibrium*
- value the role of precise observation and careful experimentation in learning about the chemistry of acids and bases
- tolerate the uncertainty involved in providing theoretical definitions for acids, bases and *equilibrium*
- value the need for safe handling, storing and disposing of chemicals and materials
- appreciate the complexity of environmental problems, such as acid deposition, that have no simple solution
- foster intellectual honesty, open-mindedness and objectivity when assessing environmental effects caused by chemical *change*.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. There is a balance of opposing reactions in chemical *equilibrium systems.*	• chemical reactions involving gases, acids and bases can be described as dynamic equilibrium systems, by extending from Chemistry 20, Unit 1, the model for equilibrium in a saturated solution, and by: • stating the criteria that apply to a system at equilibrium; e.g., closed system, constancy of properties, evidence of reversibility, equal rates of forward and reverse reactions • writing and interpreting chemical reaction equations for chemical systems at equilibrium • relating the reversibility of reactions in electrochemical cells to equilibrium • calculating equilibrium constants/concentrations for simple homogeneous chemical systems when: – concentrations at equilibrium are known – initial concentrations and one equilibrium concentration are known – the equilibrium constant and one equilibrium concentration are known • predicting if reactants or products are favoured in a reversible reaction, on the basis of the magnitude of the equilibrium constant • using Le Chatelier's principle to predict, qualitatively, shifts in equilibrium caused by changes in temperature, pressure, volume or concentration • explaining that catalysts do not affect the concentrations at equilibrium, only the time it takes for a system to reach equilibrium.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that many chemical reactions can be described as dynamic equilibrium systems by stating the criteria that identify them; writing equations, calculating equilibrium constants and concentrations for chemical systems at equilibrium, and by designing and performing experiments to analyze, qualitatively, shifts in equilibrium, within the context of:
• identifying variables and performing an experiment to test, qualitatively, predictions of equilibrium shifts.	• applying equilibrium principles to analyze everyday phenomena; e.g., the higher concentration of red blood cells in the circulatory systems of people living at high altitudes; carbon dioxide gas escaping from an open bottle of pop; the precipitation of limestone in caves; the rapid corrosion of metals in the presence of an acid; the role of oceans in the carbon cycle OR • analyzing industrial processes, such as the Haber–Bosch process for producing ammonia, and the Solvay process for making sodium carbonate, on the basis of equilibrium principles OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Acid and base *systems* are quantitatively and qualitatively described.	• acid and base systems are quantitatively and qualitatively described in a variety of ways, by extending from Science 8, Unit 1, Science 9, Unit 5 and Science 10, Unit 3, the properties of solutions, acids and bases, and from Chemistry 20, Unit 1, the definitions for acids, bases and pH, and by: • explaining the pH/pOH scale in terms of logarithms • defining K_w, K_a and K_b • calculating $H_3O^+_{(aq)}$ and $OH^-_{(aq)}$ concentrations, pH and pOH for solutions, using the ionization constant for water, K_w • predicting, qualitatively, changes in pH and pOH when a solution is diluted • differentiating between strength and concentration in acids and bases on the basis of empirical properties • comparing strong and weak acids and strong and weak bases, using equilibrium principles • performing calculations to determine any of pH, pOH, $[H_3O^+_{(aq)}]$, $[OH^-_{(aq)}]$, K_a, or K_b from the masses of solute, volumes and concentrations of solutions • performing calculations to determine masses of solutes, volumes or concentrations of solutions from pH, pOH, $[H_3O^+_{(aq)}]$, $[OH^-_{(aq)}]$, K_a and K_b.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that acid and base systems are quantitatively described, using pH, pOH, $[H_3O^+_{(aq)}]$, $[OH^-_{(aq)}]$, K_w, K_a, K_b, and concentration; and by performing calculations to determine any of the above from empirical data, and differentiating among strong and weak acids and bases and other solutions, within the context of:
• designing and performing an experiment to differentiate among strong and weak acids and bases and a variety of neutral solutions • calculating K_a and K_b from provided empirical data.	• describing the significance of pH in the formulation of various products, in the maintenance of viable aquatic and terrestrial environments, and in the body fluids of living systems; and understanding the importance of chemical principles to explain the functioning of products and processes OR • tracing, from a historical perspective, the development of the pH scale as an example of the way scientists have always strived to improve communication OR • explaining the significance of strength and concentration in chemical spills, in transport of dangerous goods, and in acid deposition; and discussing the need for society and individuals to protect the environment for future generations OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Acid–base chemistry involves proton transfer.	• Brønsted–Lowry acid–base reactions involve proton transfer, by extending from Chemistry 20, Unit 1, the Arrhenius definitions for acids and bases and neutralization, and from Chemistry 20, Unit 2, quantitative relationships in chemical changes, and by: • writing and interpreting chemical reaction equations illustrating the Brønsted–Lowry definition of acids and bases and neutralization • identifying conjugate pairs of Brønsted–Lowry acids and bases in chemical reaction equations • defining and describing indicators and explaining their colour changes in terms of an equilibrium shift • describing examples of substances that can act as either proton acceptors or proton donors (amphiprotic/amphoteric species) • describing examples of substances that can accept or donate more than one proton, and writing and interpreting related chemical equations • performing calculations related to quantitative reactions between acids and bases, including excess reagents in strong acid–strong base combinations • differentiating between indicator end point and equivalence point • explaining how buffers maintain a relatively constant pH when small amounts of acid, base or solvent are added to an aqueous system • providing examples of buffers that operate in living systems; e.g., in blood.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*

STS CONNECTIONS

- understanding the Brønsted–Lowry definition of acids and bases by analyzing, predicting and writing chemical equations for acid and base reactions; explaining indicators, buffers and titration; performing calculations related to reactions between strong acids and strong bases; and by designing, performing and evaluating experiments to investigate acids, bases and buffer action; performing a titration experiment, and drawing and interpreting titration curve graphs, within the context of:
  - explaining, from a historical perspective, the limitations of acid–base concepts in explaining observed phenomena and the ways in which proposed theories for acids and bases have been supported, modified or refuted

    OR

  - explaining, using chemical principles, the formation of acid deposition, describing the environmental impact and the measures being taken by industries to reduce emissions, and evaluating the problem of acid deposition, recognizing that a practical solution is limited by current scientific knowledge and technology and may require a compromise between competing priorities

    OR

  - analyzing, on the basis of chemical principles, the application of acids, bases, indicators and buffers; e.g., in processing and storage of food, in pharmaceuticals, in cleaning aids, fertilizers and other industrial products

    OR

  - any other relevant context.

SKILLS

- predicting the most likely acid–base reaction, using tables of relative acid–base strength
- designing and performing an experiment to determine the properties of organic and inorganic acids
- standardizing an acid or base solution, using primary standards
- performing a titration experiment and related calculations to determine the concentration of an acid or base solution
- using a pH meter and laboratory glassware related to titrations
- using indicators to determine the approximate pH of an acid or base solution
- drawing and interpreting titration curve graphs, using data from titration experiments involving acids and bases in various combinations, including:
  - a strong acid with a strong base
  - a strong acid with a weak base
  - a weak acid with a strong base
  - a strong acid with a polybasic species
  - a strong base with a polyprotic species
- designing, performing and evaluating an experiment to test buffer action.

PHYSICS 20–30

A. PROGRAM OVERVIEW

RATIONALE AND PHILOSOPHY

Physics is the study of matter and energy and their interactions. Through the study of physics, learners are given an opportunity to explore and understand the natural world and to become aware of the profound influence of physics in their lives. Learning is facilitated by relating the study of physics to what the learners already know, deem personally useful and consider relevant. Learning proceeds best when it originates from a base of concrete experiences presenting an authentic view of science in the context of physics. In Physics 20–30, students learn physics in relevant contexts and engage in meaningful activities. This facilitates the transfer of knowledge to new contexts. Students are encouraged to participate in lifelong learning about physics and to appreciate it as a scientific endeavour with practical impact on their own lives and on society as a whole.

Physics, as with all sciences, is an experimental discipline requiring creativity and imagination. Methods of inquiry characterize its study. In Physics 20–30, students further develop their ability to ask questions, investigate and experiment; to gather, analyze and assess scientific information; and to test scientific laws and principles and their applications. In the process, students exercise their creativity and develop their critical thinking skills. Through experimentation, and problem-solving activities that include the integration of technology and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The Physics 20–30 program places students at the centre. Students are active learners and will assume increased responsibility for their learning as they work through the program. A thorough study of physics is required to give students an understanding that encourages them to make appropriate applications of scientific concepts to their daily lives and prepares them for future studies in physics. Students are expected to participate actively in their own learning. An emphasis on the key concepts and principles of physics provides students with a more unified view of the sciences and a greater awareness of the connections among them.

These science learnings will take varying amounts of time to acquire, depending on the individual learning styles and abilities of students. While each course is designed for approximately 125 hours, instructional time can be modified to meet the individual needs of students. Some students will require more than 125 hours, while others will require less.

GOALS

The major goals of the Physics 20–30 program are:

- to develop in students an understanding of the interconnecting ideas and principles that transcend and unify the natural science disciplines
- to provide students with an enhanced understanding of the scientific world view, inquiry and enterprise
- to help students attain the level of scientific awareness essential for all citizens in a scientifically literate society
- to help students make informed decisions about further studies and careers in science
- to provide students with opportunities for acquiring knowledge, skills and attitudes that contribute to personal development.

Physics 20–30 is an academic program that helps students better understand and apply fundamental concepts and skills. The focus is on helping students understand the physics principles behind the natural events they experience and the technology they use in their daily lives. The program encourages enthusiasm for the scientific enterprise and develops positive attitudes about physics as an interesting human activity with personal meaning. It develops in students the knowledge, skills and attitudes to help them become capable of, and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities.

B. LEARNER EXPECTATIONS

GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for the specific learner expectations covered in section C. The general learner expectations are developed in two categories: *program* expectations and *course* expectations.

PROGRAM GENERAL LEARNER EXPECTATIONS

The *program* general learner expectations are broad statements of science attitudes, knowledge, skills and science, technology and society (STS) connections that students are expected to achieve in all of the senior high school science programs. These *program* general learner expectations are further refined through the *course* general learner expectations and then developed in specific detail through the study of individual units in each of Physics 20 and Physics 30. All expectations follow a progression from Science 10 through to Physics 30, and though listed separately, are meant to be developed in conjunction with one another, within a context.

ATTITUDES

Students will be encouraged to develop:

- enthusiasm for, and a continuing interest in, science
- affective attributes of scientists at work; such as, respect for evidence, tolerance of uncertainty, intellectual honesty, creativity, perseverance, cooperation, curiosity and a desire to understand
- positive attitudes toward scientific and technological skills involving process skills, mathematics, and problem solving
- open-mindedness and respect for the points of view of others
- sensitivity to the living and nonliving environment
- appreciation of the roles of science and technology in our understanding of the natural world.

KNOWLEDGE

Science Themes

Students will be expected to demonstrate an understanding of themes that transcend the discipline boundaries, and show the unity among the natural sciences, including:

- Change: how all natural entities are modified over time, how the direction of change might be predicted and, in some instances, how change can be controlled
- Diversity: the array of living and nonliving forms of matter and the procedures used to understand, classify and distinguish those forms on the basis of recurring patterns
- Energy: the capacity for doing work that drives much of what takes place in the Universe through its variety of interconvertible forms
- Equilibrium: the state in which opposing forces or processes balance in a static or dynamic way
- Matter: the constituent parts, and the variety of states of the material in the physical world
- Systems: the interrelated groups of things or events that can be defined by their boundaries and, in some instances, by their inputs and outputs.

SKILLS

Students will be expected to develop an ability to use thinking processes associated with the practice of science for understanding and exploring natural phenomena, problem solving and decision making. Students will also be expected to use teamwork, respect the points of view of others, make reasonable compromises, contribute ideas and effort, and lead when appropriate to achieve the best results. These processes involve many skills that are to be developed within the context of the program content.

Students will also be expected to be aware of the various technologies, including information technology, computer software and interfaces that can be used for collecting, organizing, analyzing and communicating data and information.

The skills framework presented here assumes that thinking processes often begin with an unresolved problem or issue, or an unanswered question. The problem, issue or question is usually defined and hypotheses formulated before information gathering can begin. At certain points in the process, the information needs to be organized and analyzed. Additional ideas may be generated—for example, by prediction or inference—and these new ideas, when incorporated into previous learning, can create a new knowledge structure. Eventually, an outcome, such as a solution, an answer or a decision is reached. Finally, criteria are established to judge ideas and information in order to assess both the problem-solving process and its outcomes.

The following skills are not intended to be developed sequentially or separately. Effective thinking is nonlinear and recursive. Students should be able to access skills and strategies flexibly; select and use skills, processes or technologies that are appropriate to the tasks; and monitor, modify or replace them with more effective strategies.

- Initiating and Planning
  - identify and clearly state the problem or issue to be investigated
  - differentiate between relevant and irrelevant data or information
  - assemble and record background information
  - identify all variables and controls
  - identify materials and apparatus required
  - formulate questions, hypotheses and/or predictions to guide research
  - design and/or describe a plan for research, or to solve a problem
  - prepare required observation charts or diagrams, and carry out preliminary calculations

- Collecting and Recording
  - carry out the procedure and modify, if necessary
  - organize and correctly use apparatus and materials to collect reliable data
  - observe, gather and record data or information accurately according to safety regulations; e.g., Workplace Hazardous Materials Information System (WHMIS), and environmental considerations

- Organizing and Communicating
  - organize and present data (themes, groups, tables, graphs, flow charts and Venn diagrams) in a concise and effective form
  - communicate data effectively, using mathematical and statistical calculations, where necessary
  - express measured and calculated quantities to the appropriate number of significant digits, using SI notation for all quantities
  - communicate findings of investigations in a clearly written report

- Analyzing
  - analyze data or information for trends, patterns, relationships, reliability and accuracy
  - identify and discuss sources of error and their affect on results

- identify assumptions, attributes, biases, claims or reasons
- identify main ideas

- Connecting, Synthesizing and Integrating

  - predict from data or information, and determine whether or not these data verify or falsify the hypothesis and/or prediction
  - formulate further, testable hypotheses supported by the knowledge and understanding generated
  - identify further problems or issues to be investigated
  - identify alternative courses of action, experimental designs, and solutions to problems for consideration
  - propose and explain interpretations or conclusions
  - develop theoretical explanations
  - relate the data or information to laws, principles, models or theories identified in background information
  - propose solutions to a problem being investigated
  - summarize and communicate findings
  - decide on a course of action

- Evaluating the Process or Outcomes

  - establish criteria to judge data or information
  - consider consequences and biases, assumptions and perspectives
  - identify limitations of the data or information, and interpretations or conclusions, as a result of the experimental/research/project/design process or method used
  - evaluate and suggest alternatives and consider improvements to the experimental technique and design, the decision-making or the problem-solving process
  - evaluate and assess ideas, information and alternatives

CONNECTIONS AMONG SCIENCE, TECHNOLOGY AND SOCIETY

Science, Technology and Society (STS)

Students will be expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationships among science, technology and society, including:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of processes or products based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

FURTHER READING

For a more detailed discussion on how to integrate thinking and research skills into the science classroom, refer to the publications: *Teaching Thinking: Enhancing Learning,* 1990 and *Focus on Research: A Guide to Developing Students' Research Skills,* 1990.

For further reading on integrating science, technology and society into the classroom, refer to the publication: *STS Science Education: Unifying the Goals of Science Education,* 1990.

COURSE GENERAL LEARNER EXPECTATIONS

The *course* general learner expectations are specific to each of Physics 20 and Physics 30 providing a bridge between the *program* general learner expectations and the specific learner expectations for each unit of study.

The attitudes expectations refer to those predispositions that are to be fostered in students. These expectations encompass attitudes toward science, the role of science and technology, and the contributions of science and technology toward society. The knowledge expectations are the major physics concepts in each course. The skills expectations refer to the thinking processes and abilities associated with the practice of science, including understanding and exploring natural phenomena, and problem solving. The connections among science, technology and society expectations focus on: the processes by which scientific knowledge is developed; the interrelationships among science, technology and society; and links each course to careers, everyday life and subsequent studies of physics.

Although itemized separately, the attitudes, knowledge, skills and STS connections are meant to be developed together within one or more contexts.

Physics 20–30

Attitudes

Students will be encouraged to:

- appreciate the role of empirical evidence and models in science, and accept the uncertainty in explanations and interpretations of observed phenomena
- value the curiosity, openness to new ideas, creativity, perseverance and cooperative hard work required of scientists, and strive to develop these same personal characteristics
- appreciate the role of science and technology in advancing our understanding of the natural world, be open-minded and respectful of other points of view when evaluating scientific information and its applications, and appreciate that the application of science and technology by humankind can have beneficial as well as harmful effects and can cause ethical dilemmas
- show a continuing interest in science, appreciate the need for computational competence, problem-solving and process skills when doing science, and value accuracy and honesty when communicating the results of problems and investigations
- appreciate the simplicity of, and similarity among, scientific explanations for complex, physical phenomena.

Physics 20

Students will be able to:

Knowledge

- compare and contrast scalar and vector quantities; and apply the concept of field to quantitatively explain, in terms of its source, direction and intensity, the gravitational effects of objects and systems
- describe, quantitatively, analyze and predict mechanical energy transformations, using the concepts of conservation of energy, work and power
- describe, quantitatively, analyze and predict motion with constant velocity, constant acceleration and uniform circular motion of objects and systems, using the concepts of kinematics, dynamics, Newton's laws of motion and the law of universal gravitation
- use the principles of simple harmonic motion and energy conservation to relate the concepts of uniform linear and circular motion to the behaviour and characteristics of mechanical waves

- describe, quantitatively, analyze and predict the behaviour of light, using the concepts of geometric and wave optics, and graphical and mathematical techniques

Skills

- perform investigations and tasks of their own and others' design that have a few variables and yield direct or indirect evidence; and provide explanations based upon scientific theories and concepts

- collect, verify and organize data into tables of their own design, and graphs and diagrams of others' design, using written and symbolic forms; and describe findings or relationships, using scientific vocabulary, notation, theories and models

- analyze and interpret data that yield straight- and curved-line graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and determine new variables, using the slopes of, and areas under graphs, plot corresponding graphs, and derive mathematical relationships among the variables

- use mathematical language of ratio and proportion, numerical and algebraic methods, two-dimensional vector addition in one plane, and unit analysis to solve single- and multi-step problems; and to communicate scientific relationships and concepts

Connections Among Science, Technology and Society

- apply cause and effect reasoning to formulate simple relationships for a given instance in which scientific evidence shapes or refutes a theory; and describe the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and explain the design and function of technological solutions to practical problems, using scientific principles; and relate the ways in which physics and technology advance one another, using appropriate and relevant examples

- explain for a given instance how science and technology are influenced and supported by society, and the responsibility of society, through physics and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Physics 20 to everyday life and to related and new concepts in subsequent studies of physics.

Physics 30

Students will be able to:

Knowledge

- compare and contrast scalar and vector quantities and fields; and apply the concept of field to quantitatively explain, in terms of their source, direction and intensity, electric, gravitational and magnetic effects on objects and systems

- explain, quantitatively, analyze and predict physical interactions among objects and systems, using the concepts of conservation of energy and momentum

- describe, quantitatively, analyze and predict the behaviour of electric charges in electric and/or magnetic fields, using the principles of kinematics, dynamics, conservation of energy and electric charge, electrostatics and electromagnetism

- explain, quantitatively, analyze and predict the motor and generator effect involving a single conductor; and use relevant electromagnetic principles to explain the design and function of simple electric motors, generators, meters, transformers and other simple electromagnetic devices

- illustrate, using biophysical, industrial and other examples, technological applications of electromagnetic theories and effects; and describe, quantitatively, analyze and predict the functioning of simple resistive direct current circuits, using Ohm's law and Kirchhoff's rules

- explain, quantitatively, the characteristics and behaviours of the various constituents of the electromagnetic spectrum, and algebraically solve problems, using the relationship among speed, wavelength and frequency of electromagnetic waves

- explain, citing empirical evidence, the development of an atomic theory contingent upon wave–particle duality of matter and statistical probability, and its technological application

Skills

- perform and evaluate investigations and tasks of their own and others' design that have multiple variables and yield direct or indirect evidence; and provide explanations and interpretations, using scientific theories and concepts

- collect, verify and organize data into tables, graphs and diagrams of their own design, using written and symbolic forms; and describe findings or relationships and make predictions, using scientific vocabulary, notation, theories and models

- analyze, interpret and evaluate data that yield straight- and curved-line graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and determine new variables using the slopes of, and areas under graphs, plot corresponding graphs, and use curve-straightening techniques to infer mathematical relationships among variables

- use mathematical language of ratio and proportion, numerical and algebraic methods, two-dimensional vector addition in one plane, unit analysis, and derived algebraic algorithms to solve multi-step, nonroutine problems; and communicate scientific relationships and concepts

Connections Among Science, Technology and Society

- apply cause and effect reasoning to formulate relationships for a range of instances in which scientific evidence shapes or refutes a theory; and explain the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and evaluate the design and function of technological solutions to practical problems, using scientific principles or theories; and relate the ways in which physics and technology advance one another, using appropriate and relevant examples

- explain and evaluate for a given instance, and from a variety of given perspectives, how science and technology are influenced and supported by society; and assess the ability and responsibility of society, through physics and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Physics 30 to everyday life and to related and new concepts in post-secondary studies of physics.

SPECIFIC LEARNER EXPECTATIONS

LEARNING CYCLE

The specific learner expectations consist of the knowledge, skills and attitudes that are to be addressed in Physics 20–30. The use of the learning cycle allows students to progress, from:

- an introduction framing the lesson in an STS connection relevant to the lives of the learners, and makes connections between past and present learning experiences, as well as anticipates activities to focus students' thinking on the learning outcomes of the activity

TO

- the experiential exploration of new content that provides students with a common base of experiences within which they identify and develop key concepts, processes and skills

THROUGH

- a hypothesis-building phase where concepts are developed to describe a particular aspect of their experiential exploration, and opportunities are provided to communicate their conceptual understanding, or demonstrate their skills or behaviours

TO

- an elaboration phase that extends understanding of key concepts and allows further opportunities to practise desired skills and problem-solving strategies

TO

- an application phase where the hypotheses, vocabulary and patterns previously developed are applied to new situations and related to key concepts and principles of science

TO

- a final evaluation of the significance of the new learning in an STS context to assess their understanding and abilities, and provide opportunities for evaluation of student progress toward achieving the curriculum standards.

In Physics 20–30, students examine phenomena in a variety of topics to show the relationships among all the sciences. Wherever possible, examples should be framed in the context of the learners' own experiences to enable them to make the connections between scientific knowledge and the society around them, the technology that societies have developed, and the nature of science itself.

PROGRAM OVERVIEW

The Physics 20–30 program emphasizes the science themes: *change, diversity, energy, equilibrium, matter* and *systems* as they relate to physics. These themes provide a means of showing the connections among the units of study in both courses of the program, and provide a framework for students to learn how individual sections of the program relate to the big ideas of science.

In addition to developing a solid understanding of fundamental science concepts and principles, Physics 20–30 has the goal of educating students about the nature of science and technology, and the interaction between physics and technology. Students must be aware of the tremendous impact of physics and associated technology on society, but at the same time, they must be aware of the roles and limitations of the physical sciences, science in general, and of technology in problem solving in a societal context.

PHYSICS 20

Energy is the science theme common to all units in Physics 20, with *change, diversity, equilibrium, matter* and *systems* also playing a role. *Energy* in its many forms causes *change* and determines the kind of change *matter* and *systems* undergo.

The major concepts allow connections to be drawn among the four units of the course and among all eight units in the two courses in the program.

Physics 20 consists of four units of study:

Unit 1: Kinematics and Dynamics
Unit 2: Circular Motion and Gravitation
Unit 3: Mechanical Waves
Unit 4: Light.

An examination of motion, the causes of motion and their relationship to *energy changes* in *systems* emphasizes the science theme of *change* in Unit 1. In Unit 2, the principles of *change* in and conservation of *energy* motion are extended to circular motion, and lead into an investigation of gravitation and *equilibrium* in planetary *systems*. Unit 3 considers the transfer of *energy* through *matter* by means of mechanical waves, and the characteristics of waves are studied in the context of sound. Unit 4 focuses on the nature of light, a visible form of *energy* and one of the *diverse* forms of electromagnetic radiation.

PHYSICS 30

The *diversity* of *energy* and *matter* are the predominant themes of the Physics 30 course.

The major concepts allow connections to be drawn among the four units of the course and among all eight units in the two courses in the program.

Physics 30 consists of four units of study:

Unit 1: Conservation Laws
Unit 2: Electric Forces and Fields
Unit 3: Magnetic Forces and Fields
Unit 4: Nature of Matter.

Physics 30 expands upon the concepts and skills introduced in Science 10 and Physics 20. In Unit 1, students emphasize the science theme of *equilibrium*, as exemplified by the fundamental phenomenon of conservation of *energy* and momentum in isolated *systems* in the physical universe. In Unit 2, the electrical nature of *matter* in its *diverse* forms is examined. Unit 3 investigates the *diversity* and magnetic nature of *matter*, and electromagnetic interactions and technological applications. In Unit 4, the quantum concept of *energy* and *matter* is investigated via the study of the electric nature of the atom, the photoelectric effect and the wave–particle duality of radiation; as well, the applications of nuclear energy and the radioactive nature of the atom are studied.

PHYSICS 20

UNIT 1
KINEMATICS AND DYNAMICS

OVERVIEW

Science Themes: *Change, Energy* and *Systems*

In Unit 1, students investigate *change* in position and velocity of objects and *systems* in a study of kinematics. The investigation of dynamic phenomena demonstrates that a *change* in *energy* is the manifestation of the effect of forces on the motion of objects and *systems*.

This unit extends the study of motion first introduced in Science 7, Unit 3: Force and Motion, and further developed in Science 10, Unit 4: Change and Energy, to a formal study of uniform motion, uniform accelerated motion, Newton's laws of motion, and concludes with a formal introduction to mechanical *energy*, work and power. This unit provides a foundation for further study of mechanics in subsequent units and physics courses.

The three **major concepts** developed in this unit are:

- *change* in the position and velocity of objects and *systems* can be described graphically and mathematically
- the concepts of dynamics explicitly relate forces to *change* in velocity
- work is a transfer of *energy*.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from physical interactions
- connecting, synthesizing and integrating to relate the data to the laws and principles of kinematics and dynamics
- evaluating the process or outcomes of activities investigating the concepts of kinematics and dynamics.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying motion, *energy*, work and power
- accept uncertainty in the descriptions and explanations of motion in the physical world
- be open-minded in evaluating potential applications of mechanical principles to new technology
- appreciate the fundamental role the principles of mechanics play in our everyday world
- appreciate the need for accurate and honest communication of all evidence gathered in the course of an investigation related to mechanical principles
- appreciate the need for empirical evidence in interpreting observed mechanical phenomena
- appreciate the restricted nature of evidence when interpreting the results of physical interactions.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. *Change* in the position and velocity of objects and *systems* can be described graphically and mathematically.	• the motion of objects and systems can be described in terms of displacement, time, velocity and acceleration, by extending from Science 10, Unit 4, the principles of one-dimensional motion, and by: • defining, operationally, and comparing and contrasting scalar and vector quantities • defining velocity as a change in position during a time interval • defining acceleration as a change in velocity during a time interval • comparing motion with constant velocity and variable velocity, and motion with constant acceleration and variable acceleration, average and instantaneous velocity • explaining uniform motion and uniformly accelerated motion, using position–time, velocity–time and acceleration–time graphs • applying the concepts of slope and area under a line or curve to determine velocity, displacement and acceleration from position–time and velocity–time graphs • explaining, quantitatively, two-dimensional motion, in horizontal or vertical planes, using vector components addition • explaining the uniform motion of objects, using algebraic and graphical methods, from verbal or written descriptions and mathematical data • explaining, quantitatively, the motion of one object relative to another object, using displacement and velocity vectors • using the delta notation correctly when describing change in quantities★ • using unit analysis to check the results of mathematical solutions.★ ★ To be developed throughout the course.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the motion of objects and systems in terms of position, time, velocity and acceleration, and explaining uniform motion, using graphical, algorithmic and vector methods; and by gathering, and numerically and graphically analyzing relevant data to determine mathematical relationships among acceleration, displacement, velocity and time, within the context of:
• performing experiments to demonstrate the relationships among acceleration, displacement, velocity and time, using interval timers to gather the necessary data • inferring from a graphical analysis of empirical data the mathematical relationships among acceleration, displacement, velocity and time for uniformly accelerated motion • analyzing empirical data graphically, using line-of-best-fit to discover mathematical relationships • performing experiments to determine the local value of the acceleration due to gravity.	• evaluating the design of structures and devices, such as roadway approaches and exit ramps, airport runways and carnival rides, in terms of kinematics principles OR • analyzing the use of kinematics concepts in the synchronization of traffic lights OR • researching and reporting on the use of kinematics principles in traffic accident investigations OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The concepts of dynamics explicitly relate forces to *change* in velocity.	• changes in velocity are the result of a non-zero net force, by recalling from Science 7, Unit 3, the notions of force, inertia and friction, and by: • comparing and contrasting among mass, volume and weight • explaining how a force effects a change in motion • applying Newton's first law of motion to explain an object's state of rest or uniform motion • applying Newton's second law of motion, and using it to relate force, mass and acceleration • relating Newton's third law of motion to interaction between two objects, recognizing that the two forces, equal in magnitude and opposite in direction, act on different bodies • determining, quantitatively, the net or resultant force acting on an object, using vector components addition graphically and mathematically • applying Newton's laws of motion to solve, algebraically, linear motion problems in horizontal, vertical and inclined planes, near the surface of Earth (whenever friction is included, only the resistive effect of the force of friction is considered) • solving projectile motion problems near the surface of Earth, ignoring air resistance. .

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding changes in velocity in terms of non-zero net forces, and applying Newton's laws of motion to explain, and quantitatively solve, linear motion problems; and by performing experiments to gather and mathematically analyze data relevant to dynamics problems, within the context of:
• performing experiments to determine the relationships among acceleration, force and mass, using interval timers to gather the necessary data • using free-body diagrams in organizing and communicating the solutions of dynamics problems.	• explaining the movement of passengers in a vehicle changing speed and/or direction, in terms of the law of inertia OR • assessing the design and use of injury prevention devices in cars and sports (business and industry) in terms of the principle of inertia and Newton's laws OR • evaluating the role of the principles of mechanics in solving practical problems and addressing societal needs when legal restrictions, such as seat belts and speed limits, are established OR • researching and reporting on the use of dynamics principles in traffic accident investigations OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Work is a transfer of *energy*.	• mechanical energy exchanges involve changes in kinetic and/or potential energy, by extending the mechanical energy concepts studied in Science 10, Unit 4, and by: • defining work as a measure of the mechanical energy transferred • defining, quantitatively, power as the rate of doing work • analyzing, quantitatively, mechanical energy transformations, using the law of conservation of mechanical energy.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding and quantitatively analyzing mechanical energy transformations, using the concept of conservation of mechanical energy; and by investigating and illustrating the relationships among mechanical energy, work and power, using empirical evidence and algorithms, within the context of:
• performing experiments investigating the relationships among mechanical energy, work and power • illustrating the relationships among mechanical energy, work and power, using empirical data and algorithms.	• evaluating the design of energy transfer devices, such as simple household tools, elevators, escalators and ski lifts, in terms of the relationships among mechanical energy, work and power OR • investigating and reporting on careers, supported by societal needs and interests, that require an understanding and application of kinematics and dynamics OR • any other relevant context.

UNIT 2
CIRCULAR MOTION AND GRAVITATION

OVERVIEW

Science Themes: *Change, Energy, Equilibrium* and *Systems*

In Unit 2, students investigate *change* in motion and position of objects, and the dynamic *equilibrium* of planetary *systems,* in a study of circular motion and gravitation. Uniform circular motion is seen as an example of conservation of *energy.*

This unit extends the study of kinematics and dynamics from Unit 1 to uniform circular motion, an introduction to periodic motion. Two-dimensional vectors and Newton's laws are used to analyze and explain circular motion with uniform orbital speed. The concept of "field" is introduced to explain gravitational effects; and the role that the physical principles of circular motion had in the development of Newton's universal law of gravitation is examined. This unit provides a foundation for further study of mechanics and fields in subsequent units and physics courses.

The two **major concepts** developed in this unit are:

- Newton's laws of motion can be used to explain uniform circular motion
- gravitational effects extend throughout the Universe.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from physical interactions
- connecting, synthesizing and integrating to relate the data to the principles of uniform circular motion and gravitation
- evaluating the process or outcomes of activities investigating the concepts of circular motion and gravitation.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying motion and gravitational effects
- accept uncertainty in the descriptions and explanations of circular motion and gravitation in the physical world
- be open-minded in evaluating potential applications of the principles of circular motion and gravitation to new technology
- appreciate the fundamental role the principles of circular motion have in explaining observed artificial and natural phenomena
- appreciate the fundamental role the principles of circular motion and gravitation play in our everyday world
- appreciate the contribution made by Kepler, Newton and Cavendish to the development of Newton's universal law of gravitation.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Newton's laws of motion can be used to explain uniform circular motion.	• uniform circular motion requires a non-zero net force of constant magnitude, by: • describing uniform circular motion as a special case of two-dimensional motion • describing forces in circular motion as gravitational, frictional, electrostatic • explaining, quantitatively, that the acceleration in circular motion is centripetal • explaining, quantitatively, circular motion in terms of Newton's laws of motion • solving, quantitatively, circular motion problems, using algebraic and/or graphical vector analysis • explaining, quantitatively, the relationships among speed, frequency, period and circular motion • analyzing, quantitatively, the motion of objects moving with constant speed in horizontal or vertical circles near the surface of Earth.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding uniform circular motion and its relationship to Newton's laws of motion, and explaining and solving, quantitatively, circular motion problems, using algebraic and/or graphical vector analysis; and by determining, empirically, the relationships among net force acting on an object moving in uniform circular motion, frequency, mass, speed and path radius, within the context of:
• performing experiments to determine the relationships among the net force, acting on an object in uniform circular motion, frequency, mass, speed and path radius.	• analyzing the principles of a centrifuge and its applications to solve problems in industry and research OR • analyzing the motion of a car, moving through a curve with constant speed, in terms of Newton's laws as applied to uniform circular motion, friction and road banking OR • analyzing, in terms of Newton's laws as applied to uniform circular motion, the motion of carnival rides and playground equipment moving in horizontal or vertical circles OR • analyzing, qualitatively, the function of a potter's wheel, in terms of Newton's laws as applied to uniform circular motion OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Gravitational effects extend throughout the Universe.	• gravity is a universal force of nature, by: • explaining, qualitatively, how mechanical understanding of circular motion and Kepler's laws were used in the development of Newton's universal law of gravitation • explaining, qualitatively, the principles pertinent to the Cavendish experiment used to determine the gravitational constant, *G* • relating the universal gravitational constant to the local value of the acceleration due to gravity • predicting, quantitatively, changes in weight that objects experience on different planets • defining "field" as a concept explaining action at a distance, and applying it to describing gravitational effects • applying, quantitatively, Newton's second law, combined with the universal law of gravitation, to explain planetary and satellite motion, using the circular motion approximation • predicting the mass of a planet from the orbital data of a satellite in uniform circular motion • explaining, qualitatively, the shape of our solar system, and that of galaxies, in terms of Newton's laws of motion and Newton's law of gravitation.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that gravity is a universal force of nature, and defining "field" as a concept explaining action at a distance and applying it to describing gravitational effects, and explaining, quantitatively, planetary and satellite motion, using Newton's second law combined with Newton's universal law of gravitation and the circular motion approximation, within the context of:
• relating the gravitational force, using Newton's second law, to planetary and satellite motion problems.	• discussing and evaluating the potential applications of "microgravity" conditions in research and manufacturing to advance scientific and technological knowledge, and the influence of the needs, interests and financial support of society on scientific and technological research OR • examining the functioning and applications of geosynchronous satellites to advance scientific and technological knowledge, and the influence of the needs, interests and financial support of society on scientific and technological research OR • explaining the mass distribution in our solar system and/or the Universe in terms of the chaos theory and gravitational attraction OR • assessing objectively, in terms of scientific principles and/or the needs, interests and financial support of society, the desirability of designing and building a space station, and evaluating the impact that living on a space station has on quality of life OR • any other relevant context.

UNIT 3
MECHANICAL WAVES

OVERVIEW

Science Themes: *Energy* and *Matter*

In Unit 3, students investigate the transmission of *energy* through *matter* by means of mechanical waves.

This unit uses a brief introduction to simple harmonic motion as a bridge from circular periodic motion to linear oscillation. The concepts of motion and *energy* are extended to the study of mechanical wave characteristics and behaviour. Sound is used as an example of a mechanical wave and to enhance understanding of wave behaviour and characteristics. This unit serves as a link between Unit 1: Kinematics and Dynamics, and Unit 4: Light.

The two **major concepts** developed in this unit are:

- many vibrations are simple harmonic
- waves are a means of transmitting *energy*.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from observations of mechanical wave phenomena
- connecting, synthesizing and integrating to predict mechanical wave behaviour, from data or information
- evaluating the process or outcomes of activities investigating the concepts of mechanical waves.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying wave behaviour and characteristics
- accept uncertainty in the descriptions and explanations of wave phenomena in the physical world
- be open-minded in evaluating potential applications of mechanical wave principles to new technology
- appreciate the fundamental role the principles of mechanical waves have in explaining observed artificial and natural phenomena
- appreciate the fundamental role the principles of mechanical waves play in our everyday world.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Many vibrations are simple harmonic.	• simple harmonic motion is used to describe mechanical wave motion, by: • defining simple harmonic motion as motion toward a fixed point, with an acceleration, due to a restoring force, that is proportional to the displacement from the equilibrium position • explaining, qualitatively, the relationships among displacement, acceleration, velocity and time, for simple harmonic motion, in terms of uniform circular motion • explaining, quantitatively, the relationships among kinetic, potential and total mechanical energies of a mass executing simple harmonic motion • defining resonance, and giving examples of mechanical and/or acoustical resonance • describing wave motion in terms of the simple harmonic motion of particles.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that simple harmonic motion links uniform circular motion to the characteristics of mechanical waves, and explaining and solving, using mathematical methods, simple harmonic motion problems; and by relating, from empirical evidence, frequency and period of a simple harmonic motion to the physical characteristics of a system, within the context of:
• designing and performing an experiment to demonstrate that simple harmonic motion can be observed in objects within certain limits, and relate the frequency and period of the motion to physical characteristics of the system; e.g., a mass on a light, vertical spring or a simple pendulum	• analyzing, qualitatively, in terms of scientific principles, dampening forces in real-life examples of simple harmonic motion; e.g., springs in vehicle suspensions, pendulum clocks, metronomes OR
• observing the phenomenon of mechanical and acoustical resonance	• analyzing seismic waves and their impact on structures on Earth's surface OR
• predicting and verifying the conditions required for mechanical resonance to occur.	• assessing the implications of resonance in the design of structures and devices with moving parts; e.g., cars, bridges, buildings OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Waves are a means of transmitting *energy*.	• energy from simple harmonic motion can be transmitted as a wave through a medium, by: • describing medium particle vibrations as the source of mechanical waves • comparing and contrasting energy transmission by matter that moves and by waves that move • explaining the characteristics of waves in terms of the direction of vibration of the medium particles in relation to the direction of propagation of the disturbance • defining and using the terms wavelength, amplitude, transverse and longitudinal, in describing waves • explaining how a wave travels with a speed determined by the characteristics of the medium • relating the frequency of a wave to the period of the source, and the speed of propagation to the frequency and wavelength • predicting, quantitatively, and verifying, the effects of changing one, or a combination, of the variables in the relationship $v = f\lambda$ • explaining the behaviour of waves at the boundaries between mediums; e.g., reflection and refraction at "open" and "closed" ends • predicting the resultant displacement when two waves interfere • explaining the Doppler effect on a stationary observer with a moving source, and a moving observer with a stationary source.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*

STS CONNECTIONS

- understanding that mechanical waves are a means of transmitting energy through a medium, and describing and explaining wave characteristics and behaviour, such as reflection, refraction, interference, resonance and the Doppler effect, using appropriate terms; and by gathering and analyzing empirical evidence describing the characteristics and behaviour of mechanical waves, within the context of:

  - investigating the application of acoustical phenomena, and other wave characteristics and behaviour, to solve practical problems in recreational, medical, industrial and research technology, and the influence of the needs, interests and financial support of society on scientific and technological research; e.g., sonar, ultrasound, sonography, radar, pipe organs, wind and brass instruments

    OR

  - assessing the impact of noise and sound in daily life, and evaluating the design and functioning of noise reduction devices and their impact on the quality of life

    OR

  - investigating the requirements and potential of careers, supported by societal needs and interests, involving sound

    OR

  - any other relevant context.

SKILLS

- determining the speed of a water wave in a ripple tank or a wave pulse travelling along a stretched spring, flexible coil or rope
- observing the phenomena of reflection, refraction, diffraction and interference of mechanical waves
- drawing a diagram of the resultant wave, when two waves interfere, using the principle of superposition
- designing and performing experiments to measure the speed of sound in air, using resonance in an air column that is closed at one end
- identifying the differences between sounds, such as loudness, pitch and quality.

UNIT 4
LIGHT

OVERVIEW

Science Themes: *Diversity* and *Energy*

In Unit 4, students investigate *diversity* and *energy,* in a study of the nature and behaviour of light.

This unit applies prior knowledge from Unit 3 about the characteristics and behaviour of waves, in addition to the principles and methods of ray optics, to the phenomenon of light. The nature of science is particularly emphasized by the attention paid to the use of models in the development of a theory of light. This unit provides a foundation for the study of electromagnetic radiation and the photon model of light in Physics 30.

The two **major concepts** developed in this unit are:

- geometric optics is one model used to explain the nature and behaviour of light
- the wave model of light improves our understanding of the behaviour of light.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from observations of light phenomena, and identifying the limits of the data or information obtained
- connecting, synthesizing and integrating to relate the data to the behaviour and characteristics of light
- evaluating the process or outcomes of activities investigating the characteristics and behaviour of light.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- appreciate that models are modified, as new and/or conflicting evidence is presented
- appreciate the need for computational competence in quantifying the behaviour of light
- accept uncertainty in the descriptions and explanations of the behaviour and nature of light
- be open-minded in evaluating potential applications of the principles of the nature of light to new technology
- appreciate the fundamental role of models in explaining observed natural phenomena
- appreciate the fundamental role the principles of the nature and behaviour of light play in our everyday world.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Geometric optics is one model used to explain the nature and behaviour of light.	• geometric optics can be used to explain observed phenomena of light, by: • citing evidence for the linear propagation of light • explaining a method of measuring the speed of light • calculating *c*, given experimental data of various methods employed to measure the speed of light • defining a ray as a straight line representing the rectilinear propagation of light • explaining, using ray diagrams, the phenomena of dispersion, reflection and refraction at plane and uniformly curved surfaces • stating and using Snell's law in the form of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ • deriving the curved mirror equation from empirical data • solving reflection and refraction problems, using algebraic, trigonometric and graphical methods • analyzing simple optical systems, consisting of no more than two lenses or one mirror and one lens, using algebraic and/or graphical methods.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by: • designing and performing an experiment demonstrating that light travels in a straight line when in a uniform medium • performing experiments demonstrating reflection and refraction at plane and uniformly curved surfaces • deriving the mathematical representations of the laws of reflection and refraction, from the data obtained from these experiments • performing an experiment to determine the index of refraction of several different substances, and predicting the conditions required for total internal reflection to occur.	*Students should be able to demonstrate the interrelationships among science, technology and society, by:* • understanding and explaining observed light phenomena, reflection, refraction and dispersion in terms of geometric optics, and solving reflection and refraction problems, using algebraic, trigonometric and graphical means; and by gathering and mathematically analyzing relevant data describing the characteristics and behaviour of light, within the context of: • assessing the influence of available technology on the experimental designs used by Galileo, Römer, Huygens, Fizeau, Foucault, Michelson and contemporary experimenters, to measure the speed of light OR • assessing the processes in which light affects living organisms, and the use of light technology to solve practical problems; e.g., growth, vision OR • evaluating and explaining technological and biological applications of linear propagation, reflection, refraction and total internal reflection of light to solve practical problems, and how these applications reflect the needs, interests and financial support of society; e.g., binoculars, eyeglasses, design of greenhouses, solar collectors, fibre optics OR • investigating the requirements and potential of careers, supported by societal needs and interests, involving optics OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The wave model of light improves our understanding of the behaviour of light.	• wave optics can explain light phenomena that geometric optics cannot, by recalling from Unit 3, the behaviour of waves during reflection, refraction and interference, and by: • comparing the explanations of reflection and refraction by the particle theory and by the wave theory of light • explaining, using the wave theory of light, the phenomena of reflection and refraction • explaining why geometric optics fail to adequately account for the phenomena of diffraction, interference and polarization • explaining, qualitatively, diffraction and interference, using the wave model of light • explaining how the results of Young's double-slit experiment support the wave theory of light • solving double-slit problems, using $\lambda = \frac{xd}{nl}$, and diffraction grating problems, using $\lambda = \frac{d \sin\theta}{n}$ • explaining, qualitatively, polarization in terms of the wave model of light • demonstrating how Snell's law in the form $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$ offers support for the wave model of light.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding how the wave model explains the behaviour of light in the phenomena of interference, double-slit diffraction and polarization; and by empirically investigating and mathematically analyzing the phenomena of diffraction and interference, within the context of:
• predicting the conditions required for diffraction to be observed • performing an experiment to determine the wavelength of a light source in air or a liquid, using a Young's double-slit apparatus or a diffraction grating • predicting and performing an experiment to verify the effects on an interference pattern due to changes in any one or more of the following variables: wavelength, slit separation or screen distance.	• investigating and reporting on Newton's influence, and the role of experimental evidence, in the development of a model for the theory of light OR • identifying and explaining, qualitatively, Poisson's spot as an example of the role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted where a model predicted new light phenomena OR • analyzing, qualitatively, the structure and function of polarizing filters in everyday life and nature, in terms of scientific principles; e.g., sunglasses, photography, bees, calculator liquid crystal diodes (LCDs) OR • any other relevant context.

PHYSICS 30

UNIT 1
CONSERVATION LAWS

OVERVIEW

Science Themes: *Energy, Equilibrium* and *Systems*

In Unit 1, students investigate *energy* and *equilibrium* in the physical world, in a study of the conservation of *energy* and momentum.

In this unit, the *energy* concepts from Science 10, Unit 4: Change and Energy; and Physics 20, Unit 1: Kinematics and Dynamics, are recalled and extended. The vector nature of momentum is explored through the algebraic and graphical solution of conservation of linear momentum problems. The principles learned are reinforced by analyzing common and practical physical interactions in isolated *systems*. This unit provides a foundation for further study of mechanics in subsequent units and for post-secondary studies in physics.

The two **major concepts** developed in this unit are:

- conservation of *energy* in an isolated *system* is a fundamental physical concept
- momentum is conserved when objects interact in an isolated *system*.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from physical interactions
- connecting, synthesizing and integrating to relate the data to the laws and principles of conservation of energy and momentum
- evaluating the process or outcomes of activities investigating the concepts of conservation of energy and momentum.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying conservation of energy and momentum
- accept uncertainty in the descriptions and explanations of conservation in the physical world
- be open-minded in evaluating potential applications of conservation principles to new technology
- appreciate the fundamental role the principles of conservation play in our everyday world
- appreciate the need for simplicity in scientific explanations of complex physical interactions and the role conservation laws play in many of these explanations
- appreciate the need for accurate and honest communication of all evidence gathered in the course of an investigation related to conservation principles
- appreciate the need for empirical evidence in interpreting observed conservation phenomena
- appreciate the restricted nature of evidence when interpreting the results of physical interactions.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Conservation of *energy* in an isolated *system* is a fundamental physical concept.	• mechanical energy interactions involve changes in kinetic and potential energy, by extending energy concepts from Science 10, Unit 4, and the mechanical energy concepts and problem-solving methods studied in Physics 20, Unit 1, and by: • describing energy and mass as scalar quantities • relating the conservation of mass and energy in a qualitative analysis of Einstein's concept of mass–energy equivalence • defining mechanical energy as the sum of kinetic and potential energy • solving conservation problems, using algebraic and/or graphical analysis • analyzing and solving, quantitatively, kinematics and dynamics problems, using mechanical energy conservation concepts by extending previous problem-solving methods.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that changes in kinetic and potential energy occur in mechanical energy interactions; and analyzing and solving, quantitatively, kinematic and dynamics problems, using mechanical energy concepts, and algebraic and/or graphical analyses; and by gathering, and graphically analyzing, relevant data inferring mathematical relationships, within the context of:
• designing and performing experiments demonstrating the law of conservation of energy, and the relationship between kinetic and mechanical potential energy • using free-body diagrams (force diagrams) in organizing and communicating the solutions of conservation problems • analyzing data graphically, using curve-straightening techniques, to infer mathematical relationships.	• investigating and reporting the application of conservation principles in research and design OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Momentum is conserved when objects interact in an isolated *system.*	• conservation laws provide a simple means to explain interactions among objects, by: • describing momentum as a vector quantity • defining momentum as a quantity of motion equal to the product of the mass and the velocity of an object • relating Newton's laws of motion, quantitatively, to explain the concepts of impulse and a change in momentum • explaining, quantitatively, using vectors, that momentum appears to be conserved during one- and two-dimensional interactions in one plane among objects (the sine and cosine rules are not required) • defining, comparing and contrasting elastic and inelastic collisions, using quantitative examples • comparing scalar and vector conservation laws.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the law of conservation of momentum provides a means to explain interactions among objects; and explaining, quantitatively, using vectors and one- and two-dimensional interactions in one plane; and by obtaining and analyzing empirical evidence to demonstrate the conservation of momentum, and estimating and predicting results of interactions, within the context of:
• performing and analyzing experiments demonstrating the conservation of momentum and the principle of impulse • approximating, estimating and predicting results of interactions, based on an understanding of the conservation laws.	• assessing the role conservation laws and the principle of impulse play in the design and use of injury prevention devices in vehicles and sports; e.g., air bags, child restraint systems, running shoes, helmets OR • analyzing how the need for decreasing momentum over a long period has influenced the design of ropes used in such activities as "bunji" jumping and mountain climbing OR • investigating and reporting on a technology developed to improve the efficiency of energy transfer in a response to reconcile the energy needs of society with its responsibility to protect the environment and to use energy judiciously OR • investigating and reporting on a safety device that results in a cost saving to consumers and society, in terms of the problem addressed and its impact on quality of life OR • any other relevant context.

UNIT 2
ELECTRIC FORCES AND FIELDS

OVERVIEW

Science Themes: *Diversity, Energy* and *Matter*

In Unit 2, the *diversity* of *matter* is highlighted as its electric nature is considered in the context of electrical interactions and electric energy.

This unit covers the principles of electrostatics and how to describe the interaction of electric charges mathematically from empirical data. The concepts from Physics 20, Unit 1: Kinematics and Dynamics, are extended to charged particle dynamics. The concept of field, introduced in Physics 20, Unit 2: Circular Motion and Gravitation, is applied to electrical phenomena. The unit concludes with the consideration of electric *energy* and simple direct current (DC) circuits. This unit provides a foundation for further study of electrical principles in subsequent units and for post-secondary studies in physics.

The four **major concepts** developed in this unit are:

- the laws governing electrical interactions are used to explain the behaviour of electric charges at rest
- Coulomb's law relates electric charge to electric force
- electric field theory is a model used to explain how charges interact
- electric circuits facilitate the use of electric *energy*.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from electrical interactions
- connecting, synthesizing and integrating to relate the data to the laws and principles of electric forces and fields
- evaluating the process or outcomes of activities investigating the concepts of electric forces and fields.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying electrical interactions
- accept uncertainty in the descriptions and explanations of electrical phenomena in the physical world
- be open-minded in evaluating potential applications of electrical principles to new technology
- appreciate the fundamental role the principles of electricity play in our everyday world
- appreciate the need to follow safe practices when working with electricity
- foster a responsible attitude to environmental and social change as related to the use and production of electrical *energy*
- appreciate the restricted nature of evidence when interpreting the results of electrical interactions.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. The laws governing electrical interactions are used to explain the behaviour of electric charges at rest.	• the electrical model of matter is fundamental to the explanation of electrical interactions, by extending from Physics 20, Unit 1, and by: • describing matter as containing discrete positive and negative particles • explaining electrical interactions in terms of the law of conservation of charge • explaining electrical interactions in terms of the law of electric charge (two types of charge: like charges repel, unlike charges attract) • comparing the methods of transferring charge: conduction and induction.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the electrical model of matter is fundamental to the explanation of electrical phenomena; and explaining electrical interactions in terms of the law of conservation of charge and the law of electric charge; and by investigating, empirically, and explaining electrostatics, using the electric nature of matter, within the context of:
• performing an activity demonstrating the electrical nature of matter, using methods of electrification, and describing observations in terms of the laws of electrostatics • using safe practices when conducting electrical experiments.	• assessing how the principles of electrostatics are used to solve problems in industry and technology, and improve upon quality of life; e.g., telephones, photocopiers, electrostatic air cleaners, precipitators OR • investigating natural and artificial electrical discharge and the need for grounding in terms of scientific principles and the inability of science to provide complete answers to all questions OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Coulomb's law relates electric charge to electric force.	• Coulomb's law explains the relationships among force, charge and separating distance, by: • explaining, qualitatively, the principles pertinent to Coulomb's torsion balance experiment • explaining, quantitatively, using Coulomb's law and vectors, the electrostatic interaction between discrete point charges • comparing the inverse square relationship as it is expressed by Coulomb's law and Newton's universal law of gravitation.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the relationships among force, charge and separating distance is explained by Coulomb's law; and explaining, quantitatively, using Coulomb's law and vectors, the electrostatic interaction between discrete point charges; and by gathering and analyzing relevant data inferring the mathematical relationships among force, charge and separating distance, within the context of:
• performing an experiment demonstrating the relationships among magnitude of charge, electric force and distance • inferring the mathematical relationships among force, charge and separating distance from empirical evidence.	• comparing and contrasting the experimental designs used by Coulomb and Cavendish, in terms of the role of technology in advancing science OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Electric field theory is a model used to explain how charges interact.	• the concept of field is applied to electric interactions, by extending from Physics 20, Unit 2, the definition of field, and by: • comparing scalar and vector fields • comparing forces and fields • explaining, quantitatively, using vector addition, electric fields in terms of intensity (strength) and direction relative to the source of the field • explaining, quantitatively, using vector addition, electric fields in terms of intensity (strength) and direction relative to the effect on an electric charge • predicting, using algebraic and/or graphical methods, the path followed by a moving electric charge in a uniform electric field, using kinematics and dynamics concepts • explaining electrical interactions, quantitatively, using the conservation laws of energy and charge.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the concept of field as related to electrical interactions; and explaining, quantitatively, using vector addition electric fields in terms of intensity and direction relative to the source of the field and its effect on an electric charge; and by plotting electric fields, using field lines and linking centripetal force to the electric force, within the context of:
• plotting electric fields, using field lines, for fields induced by discrete point charges, combinations of discrete point charges (like and oppositely charged) and charged parallel plates	• evaluating electric field theory as a model used to explain the behaviour of electric charges in terms of supporting experimental evidence OR
• relating the electric force, using Newton's second law, to the motion of an electric charge following a curved path in an electric field.	• explaining, qualitatively, how the problem of protecting sensitive components in a computer from electric fields is solved OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
4. Electric circuits facilitate the use of electric *energy*.	• Ohm's law and Kirchhoff's rules are fundamental to explaining simple electric circuits, by: • defining current, potential difference, resistance and power, using appropriate terminology • defining the ampere as a fundamental SI unit, and relating the coulomb and second to it • distinguishing between conventional and electron flow current • explaining Ohm's law as an empirical, rather than a theoretical, relationship • quantifying electrical energy and power dissipated in a resistor, using Ohm's law • explaining Kirchhoff's current and voltage rules as a logical consequence of the laws of conservation of energy and charge • analyzing, quantitatively, simple series and/or parallel DC circuits in terms of the variables of potential difference, current and resistance, using Kirchhoff's rules and/or Ohm's law (solutions requiring Kirchhoff's rules to be limited to networks containing two power supplies and three branch currents).

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding and analyzing, quantitatively, simple series and parallel circuits in terms of Ohm's law and Kirchhoff's rules; and quantifying electrical energy and power dissipated in a resistor, using Ohm's law; and by determining, from empirical and theoretical evidence the relationships among electric energy/power, current, resistance and voltage, within the context of:
• determining, from empirical and theoretical evidence, the relationships among electric energy/power, current, resistance and voltage • performing an experiment to explain the relationships among current, voltage and resistance • designing, analyzing and solving simple resistive DC circuits • drawing diagrams of simple resistive DC circuits, using accepted symbols for circuit components • designing and performing an experiment demonstrating the heating effect of electric energy.	• analyzing common technological applications of electricity to solve practical problems in daily life; e.g., toasters, hair dryers, light fixtures OR • comparing and contrasting electrical energy with other energy sources with respect to such factors as cost, energy potential, risks and benefits to society, safety concerns and their impact on the quality of life of future generations OR • analyzing the use of series and parallel networks in household circuits in terms of the problems addressed OR • investigating the need for and the functioning of circuit breakers in household circuits OR • analyzing the risks of electric shock in terms of scientific principles OR • investigating the requirements and potential of careers, supported by societal needs and interests, involving electricity OR • any other relevant context.

UNIT 3
MAGNETIC FORCES AND FIELDS

OVERVIEW

Science Themes: *Diversity* and *Matter*

In Unit 3, the *diversity* of *matter* is highlighted as its magnetic nature is considered in the context of electric and magnetic interactions.

The concept of field, introduced in Physics 20, Unit 2: Circular Motion and Gravitation, is applied to magnetic phenomena. The concepts from Physics 20, Unit 1: Kinematics and Dynamics, are applied to charged particle dynamics in magnetic fields. The principles of electromagnetism introduced in Science 9, Unit 4: Electromagnetic Systems are further applied to an investigation of the functioning of electric motors, generators and transformers. The unit concludes with the consideration of the characteristics of the electromagnetic spectrum and alternating current (AC) circuits. This unit provides a foundation for further study of electromagnetic principles in Unit 4 and for post-secondary studies in physics.

The three **major concepts** developed in this unit are:

- magnetic field theory is a model used to describe magnetic behaviour
- electromagnetism pervades the Universe
- electromagnetic radiation is a physical manifestation of the interaction of electricity and magnetism.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from electromagnetic interactions
- connecting, synthesizing and integrating to relate the data to the laws and principles of magnetic forces and fields
- evaluating the process or outcomes of activities investigating the concepts of magnetic forces and fields.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying electromagnetic phenomena
- accept uncertainty in the descriptions and explanations of electromagnetic phenomena in the physical world
- be open-minded in evaluating potential applications of electromagnetic principles to new technology
- appreciate the parallelism in the characteristics of electrical, gravitational and magnetic phenomena
- appreciate the fundamental role the principles of electricity and magnetism play in our everyday world
- appreciate the need to follow safe practices when working with electricity
- appreciate the restricted nature of evidence when interpreting the results of electromagnetic interactions.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Magnetic field theory is a model used to describe magnetic behaviour.	• field theory can be used to describe magnetic interactions, by extending from Physics 20, Unit 1 and Physics 20, Unit 2, and by: • explaining the source of magnetic characteristics of matter in terms of magnetic domains • comparing the magnetic properties of Earth with those of artificial magnets • explaining magnetic interactions in terms of vector fields • comparing gravitational, electric and magnetic fields in terms of their sources and directions.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that magnetic interactions are described using field theory; and comparing and contrasting gravitational, electric and magnetic fields and interactions in terms of their source, direction and vectors; and by using field lines to show the shape and orientation of magnetic fields due to a variety of sources, within the context of:
• plotting magnetic fields, using field lines to show the shape and orientation of the magnetic fields resulting from magnetic poles or current-carrying conductors.	• evaluating magnetic field theory as a model to describe and predict observations of magnetic behaviour based on supportive evidence OR • discussing contemporary developments in the areas of electricity and magnetism, and their immediate and potential impact on daily life; e.g., superconductivity OR • investigating and reporting the affects of magnetism on the behaviour of living organisms in terms of the limitations of scientific knowledge and technology and in terms of quality of life OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Electromagnetism pervades the Universe.	• magnetic forces and fields are described in relation to electric currents, by extending electromagnetic concepts from Science 9, Unit 4, and by: • demonstrating how the discoveries of Oersted and Faraday form the foundation of the theory relating electricity to magnetism • describing a moving charge as the source of a magnetic field; and predicting the orientation of the magnetic field from the direction of motion • predicting, quantitatively, how a uniform electric and/or magnetic field affects a moving electric charge, using the relationships among charge, motion and field direction • relating and explaining, qualitatively, the interaction between a magnetic field and a moving charge as to how a magnetic field affects a current-carrying conductor • predicting, quantitatively, the effect of an external magnetic field on a current-carrying conductor • describing the effects of moving a conductor in an external magnetic field, using the analogy of a moving charge in a magnetic field • predicting, quantitatively, the effects of a magnetic field on a moving conductor • predicting, quantitatively, and verifying, the effects of changing one, or a combination, of the variables in the relationship $\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$ • explaining the relationship between, and calculating, the effective and maximum values of, voltage and current in AC devices, given appropriate information • discussing, qualitatively, Lenz's law in terms of conservation of energy; describing, giving examples, situations where Lenz's law applies.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that magnetic forces and fields are related to electric currents; and predicting, quantitatively, the effect of a uniform electric and/or magnetic field on a moving electric charge, and explaining the motor and generator effects; and by analyzing empirical evidence of magnetic field–current interactions, within the context of:
• designing, performing and analyzing experiments demonstrating magnetic field–current interactions • predicting, using the LHR or RHR (hand rules), the relative directions of motion, force and field in electromagnetic devices • relating the magnetic force, using Newton's second law, to the motion of an electric charge following a curved path in a magnetic field.	• identifying and analyzing the application of electromagnetic interactions in the functioning of several types of technology OR • explaining, qualitatively, the design and function of AC and DC motors, generators, meters and other simple electromagnetic devices, using correct scientific terminology OR • assessing the impact of the transformer and alternating current on the generation, transmission and use of electrical energy, and on quality of life OR • evaluating, objectively, electromagnetic biomedical technology, in terms of solving practical problems and the influence of the needs, interests and financial support of society for its development, such as magnetic resonance imaging (MRI) or positron emission tomography (PET) OR • analyzing the parallels among gravitational, electrical and magnetic phenomena in terms of empirical evidence, and evaluating the role the conservation laws play in the accumulation of knowledge OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Electromagnetic radiation is a physical manifestation of the interaction of electricity and magnetism.	• Maxwell's theory of electromagnetism expanded on Oersted's and Faraday's generalizations, by: • stating that electromagnetic radiation is the result of accelerating electric charges, and demonstrates wavelike behaviour • comparing and contrasting the constituents of the electromagnetic spectrum on the basis of frequency, wavelength and energy • solving problems algebraically, using the relationships among speed, wavelength, frequency, period and/or distance, of electromagnetic waves • comparing and contrasting natural and technological processes by which the major constituents of the electromagnetic spectrum are produced • explaining, qualitatively, Maxwell's theory of electromagnetism • explaining the propagation of electromagnetic radiation in terms of perpendicular electric and magnetic fields, varying with time, travelling away from their source at the speed of light • explaining, qualitatively, how different types of electromagnetic radiation interact with matter, including biological effects; e.g., microwaves, ultraviolet radiation, X-rays.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that electromagnetic radiation is a physical manifestation of the interaction of electricity and magnetism; and explaining the propagation of electromagnetic radiation in terms of electric and magnetic fields; and by demonstrating the wavelike behaviour of electromagnetic radiation; and by predicting the conditions required for electromagnetic radiation emission, within the context of:
• performing experiments, and/or using simulations, demonstrating the wavelike behaviour of electromagnetic radiation • predicting the conditions required for electromagnetic radiation emission.	• evaluating the risks and benefits of using electromagnetic radiation in technological solutions to practical problems; in terms of the quality of life, the limitations of science and technology, and societal needs, interests and financial support OR • researching, reporting on and evaluating the use of electromagnetic radiation technology in such scientific fields as biology, chemistry, medicine, astronomy, in terms of societal needs, interests and financial support, and the contribution to the accumulation of scientific knowledge OR • investigating the requirements and potential of careers, supported by societal needs and interests, involving electromagnetism OR • any other relevant context.

UNIT 4
NATURE OF MATTER

OVERVIEW

Science Themes: *Energy* and *Matter*

In Unit 4, students investigate the science themes of *energy* and *matter,* as the electric nature of *matter* is considered in the context of developing and understanding of quantum concepts, atomic theory and nuclear processes.

Building on previous learning from Science 10, Unit 3: Energy and Matter in Chemical Change, the discovery of the electron and the development of the quantum model of the atom is studied. The study of the photoelectric effect and the photon model of light provides a link to Physics 20, Unit 4: Light, where the wave model of light is emphasized. The unit concludes with the study of radiation, the characteristics of fission and fusion reactions, quantization of *energy* and how *energy* levels in nature support modern atomic theory. This unit provides a foundation for post-secondary studies in related areas.

The four **major concepts** developed in this unit are:

- the atom has an electric nature
- the photoelectric effect requires the adoption of the photon model of light
- nuclear fission and fusion are nature's most powerful *energy* sources
- *energy* levels in nature support modern atomic theory.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from experiments, empirical and theoretical evidence for the electron and quantum concepts
- connecting, synthesizing and integrating to relate the data to a theoretical model of the atom, and to the principles of the wave–particle duality of *matter*
- evaluating the process or outcomes of activities investigating quantum concepts and the wave–particle duality of matter.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate that models are modified as new and/or conflicting evidence is presented
- appreciate the role of mathematics in assessing the risks and benefits of radioactivity and the commercial use of nuclear *energy*.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. The atom has an electric nature.	• the discovery of the electron contributed to the formulation of quantum concepts and atomic models, by extending from Science 10, Unit 3, and by: • explaining how the discovery of cathode rays contributed to the development of atomic models • explaining Thomson's experiment and the significance of the results • deriving the relationship $\frac{q}{m} = \frac{v}{BR}$, using circular motion and charged particles in electric and magnetic field concepts • explaining Millikan's experiment and its significance relative to charge quantization • relating the electronvolt, as a unit of energy, to the joule.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding and explaining how technological advances and experimental evidence contributed to the formulation of models of the atom; and by determining the charge to mass ratio of the electron, and the mass of an electron and/or ion, given appropriate empirical data, within the context of:
• performing an experiment, or using simulations, to determine the charge to mass ratio of the electron • determining, in quantitative terms, the mass of an electron and/or ion, given appropriate empirical data.	• analyzing how the identification of the electron and its characteristics is an example of the interaction of science and technology OR • evaluating how, in the scientific process, discoveries are often missed by investigators failing to identify and/or correctly interpret evidence; e.g., X-rays OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The photoelectric effect requires the adoption of the photon model of light.	• the quantum concept is required to explain adequately some natural phenomena, by extending from Physics 20, Unit 4, and by: • explaining the necessity for Planck to introduce the quantum of energy concept to explain blackbody radiation • defining the photon as a quantum of electromagnetic radiation • describing how Hertz discovered the photoelectric effect while investigating electromagnetic waves • explaining the photoelectric effect in terms of the intensity and wavelength of the incident light and surface material • assessing the assumptions made by Einstein in explaining the photoelectric effect • defining threshold frequency as the minimum frequency giving rise to the photoelectric effect; and work function as the energy binding an electron to a photoelectric surface • explaining the relationship between the kinetic energy of a photoelectron and stopping voltage • using Einstein's equation, quantitatively, to describe photoelectric emission • describing the photoelectric effect as a phenomenon that supports the notion of the wave–particle duality of electromagnetic radiation • explaining X-ray production as an inverse photoelectric effect, and predicting, quantitatively, the short wavelength limit of X-rays produced, given appropriate data • explaining, qualitatively, the Compton effect and the de Broglie hypothesis applying the laws of mechanics, conservation of momentum and energy, to photons, as another example of wave–particle duality.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that an adequate explanation of some natural phenomena requires the quantum concept; and describing the photoelectric effect as evidence for the notion of wave–particle duality of electromagnetic radiation; and by investigating, empirically, the photoelectric effect, within the context of:
• performing an experiment demonstrating the photoelectric effect and interpreting the data obtained • predicting and verifying the effect that changing the intensity and/or frequency of the incident radiation or the material of the photocathode has on photoelectric emission.	• analyzing, in general terms, the functioning of various technological applications of the photoelectric effect to solve practical problems; e.g., automatic door openers, burglar alarms, light meters, smoke detectors OR • discussing why the photoelectric effect could not be explained, using the wave model of electromagnetic radiation, and thus required a new hypothesis OR • identifying industrial and scientific uses of X-rays; e.g., X-ray examination of welds, crystal structure analysis OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Nuclear fission and fusion are nature's most powerful *energy* sources.	• the processes of nuclear fission and fusion are nature's most powerful energy sources, by: • using the isotope notation to describe and identify common nuclear isotopes, and determine the number of each nucleon of an atom • describing the nature and behaviour of alpha, beta and gamma radiation • writing nuclear equations for alpha and beta decay • performing simple, nonlogarithmic, half-life calculations • predicting the particles emitted by a nucleus from the examination of representative transmutation equations • explaining, qualitatively, how radiation is absorbed by matter, and compare and contrast the biological effects of different types of radiation • comparing and contrasting the characteristics of fission and fusion reactions • explaining, qualitatively, the importance of Einstein's concept of mass–energy equivalence • relating, qualitatively, the mass defect of the nucleus to the energy released in nuclear reactions.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the processes of nuclear fission and fusion are nature's most powerful energy sources; and describing the nature of particle radiation and nuclear decay, and explaining, qualitatively, the importance of the concept of mass–energy equivalence in nuclear reaction processes; and by analyzing empirical nuclear decay data, and performing a risk/benefit analysis of a nuclear energy application, within the context of:
• using library resources to research and report on selected scientists who contributed to our understanding of the structure of the nucleus • inferring radiation properties from experimental data provided • graphing data for radioactive decay and interpolating values for half-life • interpreting some common nuclear decay chains • performing a qualitative risk/benefit analysis of a nuclear energy application.	• assessing the value to society of nuclear and particle research OR • evaluating the applications of radiation phenomena and technologies in research, medicine, agriculture, industry; e.g., isotope tracing, food irradiation OR • assessing the risks and benefits of exposure to natural background radioactivity and artificially induced radioactivity; e.g., air travellers to cosmic radiation, dental X-rays OR • evaluating, qualitatively, the risks and benefits of using fission and/or fusion as commercial sources of energy, in terms of the limitations of scientific knowledge and technology, and the ability and responsibility of society to protect the environment and to use natural resources judiciously to ensure quality of life for future generations OR • investigating the requirements and potential of careers, supported by societal needs and interests, involving nuclear physics OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
4. *Energy* levels in nature support modern atomic theory.	• the Rutherford–Bohr model of the atom represents a synthesis of classical and quantum concepts, by: • explaining, qualitatively, the significance of the results of Rutherford's scattering experiment in terms of the nature and role of the nucleons; and the size and mass of the nucleus and the atom, which lead to the proposal of a planetary model of the atom • explaining why Maxwell's theory of electromagnetism predicts the failure of a planetary model of the atom • describing why each element has a unique line spectrum, and comparing and contrasting the characteristics of continuous and line spectra • explaining, qualitatively, the conditions necessary to produce line emission and line absorption spectra • explaining the quantum implications of the line absorption and the line emission spectra, and determining any variable in the Balmer equation $\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ • explaining Bohr's concept of "stationary states" and their relationship to line spectra of atoms; and using the frequency/wavelength of an emitted photon to determine the energy difference between states • explaining the relationship between hydrogen's absorption spectrum and its energy levels • describing how the Bohr atom can be used to predict the ionization energy of hydrogen, and to calculate the allowed radii of the hydrogen atom • describing how the Rutherford–Bohr model has been further refined, by applying quantum concepts to a purely mathematical model based on probability and waves • comparing and contrasting, qualitatively, the Rutherford, the Bohr and the quantum model of the atom.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the Rutherford–Bohr model offers a restricted explanation of the structure of the atom, and that a mathematical model provides a fuller explanation of the empirical evidence of energy levels within the atom; and by observing line spectra and predicting potential energy transition in an atom, within the context of:
• observing representative line spectra of selected elements • predicting the conditions necessary to produce and observe line emission and line absorption spectra • predicting the potential energy transitions in the hydrogen atom, using a labelled diagram showing the energy levels.	• investigating and reporting on the use of line spectra in the study of the Universe and the identification of substances OR • describing the functioning of lasers in terms of energy level transitions and resonance OR • investigating and reporting on the application of spectra concepts in the design and functioning of lighting devices; e.g., street lights, signs OR • analyzing how quantum concepts led to technological advances that benefit society; e.g., semiconductors, electron microscopes, computers OR • investigating and reporting on the contributions made by scientists to the development of the early quantum theory; e.g., Hertz, Planck, Einstein, Bohr, Compton, Davisson, Germer OR • any other relevant context.